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About Gandhinagar Institute of Technology

Gandhinagar Institute of Technology is established by Platinum Foundation in 2006. It offers under graduate programs in Mechanical Engineering, Information Technology, Computer Engineering, Electronics and Communication Engineering, Electrical Engineering and Civil Engineering and Post graduate program in MBA (Finance, Human Resource Development, and Marketing), M.E. in Mechanical Engineering with specialization in Thermal Engineering and Computer Aided Design & Computer Aided Manufacturing and M.E. in Computer Engineering with specialization in Software Engineering.

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Our students are innovative and have excellent acceptability to latest trends and technologies of present time. Our students have also participated in various technical activities as well as sports activities and have achieved various prices at state level. We have two annual publications, a National level research journal 'GIT-Journal of Engineering and Technology (ISSN 2249–6157)' and 'GIT-a Song of Technocrat' (college magazine).

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Message from the Director

It gives me immense pleasure that the tenth issue of our National journal 'GIT-Journal of Engineering and Technology' is being published with ISSN 2249 – 6157 for tenth successive year. The annual journal contains peer reviewed technical papers submitted by the researcher of all domains of engineering and technology. The issue is a result of imaginative and expressive skill and talent of GIT family. Research papers were invited from the researcher of all domains of engineering and technology. More than 27 research papers were received. After peer review 6 papers are selected and are being published in this issue of the journal.

GIT was established in 2006 and during a short span of ten years; it has accomplished the mission effectively for which it was established. Institute has been constantly achieving the glory of excellence in the field of curricular and co-curricular activities. For the ninth consecutive year an annual technical symposium TechXtreme 2017 was successfully organized by the institute. More than 3000 students of various technical institutions across the Gujarat participated in the Techfest. Prizes worth Rs 2 lacs and trophies were given to the winners. Annual cultural event Jazba 2016 was organized with participation of more than 1500 students of the institute in various cultural events of Debate, Quiz, Essay writing, Rangoli, Music, Dance, Drama etc.

The institute is Resource Center of IIT Bombay for conduction of Spoken Tutorials on various open source software like Linux, Latex, Scilab, Python, Java, Netbeans, C, C++, Liber Office, Php MySQL, etc. Institute organize various technical seminar, expert lectures, debate competition, rangoli competition, kite flying competition, Ratri B4 Navaratri, and sports activities to nurture multifaceted talent of its students. Institute has also arranged blood donation drives and thalassemia testing program. Students have also participated and won prizes in various sports, technical and cultural events organized by other Institutions including that of GTU.

The Institute is also emphasis on academic development of its faculty members. During the year, many International and National papers has been published and presented by the faculty members. The faculty members have also been deputed to attend large number of seminars/workshops/training programs/symposiums.

Publication of the journal of national level is not possible without whole hearted support of committed and experienced Trustees of Platinum Foundation and I take an opportunity to express my deep feelings of gratitude to all of them for their constant support and motivation.

It's my privileged to compliment the staff members and the students for showing high level of liveliness throughout the year. I also congratulate the team of the 'GIT-Journal of Engineering and Technology' for their untiring effort to bring out this tenth issue of the journal.

Dr N M Bhatt
Director & Chief Editor

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Design and Analysis of Radial Flow Centrifugal Pump

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Abstract

Lots of research and development has been done in Centrifugal pump designed for higher efficiency. This paper focuses on development of the impeller design used in Centrifugal Pump. Specifically, impeller & casing both are designed for increasing the pump efficiency which is required for highly competitive market demand to achieve high product performance. This paper also compares the new design with existing design of impeller. The efficiency of centrifugal pumps drops rapidly with decrease in the specific speed of the pump. In the very low specific speed range less than 70, the pump efficiency becomes extremely low. The lower efficiency at low specific speeds is due to higher disk friction losses and formation of reverse flow in an impeller channel, increasing slip velocity and hydraulic losses. Maximum 123.74 percentage of specific speed would be achieved by using the Head Number 17 in 6 and 7 vane Radial Flow Centrifugal Pump. Here Radial Flow Centrifugal Pump is designed for the speed of 2900 rpm so as to achieve the best possible efficiency. The theoretical efficiency and hydraulic efficiency of this pump are 0.7655 and 0.6773 respectively.

***Keywords*:** C.F.pump, NPSH, impeller, efficiency, vane design, CFturbo

Nomenclature

NPSH - net positive suction head **$NPSH_r$** - net positive suction head required **N** – rotating speed **Nq** – specific speed
z - number of impeller vanes net positive suction head **β_1** - impeller blade leading edge **β_2** - impeller blade tailing edge
β - angle between relative velocity and negative direction of circumferential velocity **opt** – operation at best efficiency
f_q - impeller eyes per impeller **g** - acceleration due to gravity **H** - head **i** - incidence angle
Q - flow rate **Q_{la}** - flow rate through impeller **w** – relative velocity **U** – circumferential velocity
b - Channel width **c** - Absolute velocity of the fluid **d** - diameter of impeller **d_o** - hub diameter

Literature Review

Centrifugal pumps are turbo machine that transport liquid by raising the liquid to be pumped to a specified pressure level by imparting kinetic energy to the liquid which is then converted to pressure energy. The impeller can be described by the hub, the blades transferring energy to the fluid. In some application both shroud is omitted, in this case the impeller is termed "open impeller". The leading face of the blade of the rotating impeller experiences the highest pressure for a given radius. It is called pressure surfaces or pressure side. The opposite blade surfaces with the lower pressure accordingly is the suction surfaces or suction side. The front portion of the impeller blade near to the suction is called the Leading Edge (LE) and the part near the impeller outer diameter from where the liquid leaves the impeller is called the Trailing Edge (TE). **[1]**

Depending on the direction of the flow at the impeller exit we distinguish radial, semi-axial and axial impeller. According the terms radial, semi axial and axial pumps are used; the latter also called "propeller pumps". Impellers with a front shroud are called "closed impeller", those without front shroud are termed "semi-open impeller" and those with large cut outs in the rear shroud are designated as "open impellers". If the pressure generated by one impeller is insufficient, several impellers are arranged in series resulting in a "multistage" radial or semi-axial pump. In that type of pump diffuser are included return vanes, which direct the fluid to the impeller of the subsequent stage. Multistage pump may be equipped with double volute casings; in which case the fluid is directed to the subsequent stage thought appropriately shaped channel. **[1]**

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1.1 Problem Statement

The efficiency of centrifugal pumps drops rapidly with decrease in the specific speed of the pump. In the very low specific speed range < 70, the pump efficiency becomes extremely low. The lower efficiency at low specific speeds is due to higher disk friction losses and formation of reverse flow in an impeller channel, increasing slip velocity and hydraulic losses. Hence it becomes important that the impeller and volute/casing design be optimized so as to achieve the best possible efficiency.

1.2 Main Goal

The centrifugal pump efficiency increases by optimizing its impeller design. The initial goal was to develop an impeller through design calculations and based partly on the existing impeller design provided under a technical collaboration of Industry. The prototype for the same has to be manufactured using casting for the CLS-40 series pumps. Also, another design would be made with different blade profiles for which the prototype would be made by CNC Machine. The performances of the impeller will be experimentally verified and analysing efficiencies, then only a design would be chosen for production. The efficiency gained over the other and costs to be incurred in changing the casting if needed.

1.3 Methodology

Analysis of flow through the impeller is difficult as the flow is too complex to be modelled and hence in this paper, relations from empirical research in the field has been used. Impeller design was made with the help of two methods proposed by Johannes Friedrich Gulich and Val s Lobanoff, Robert R Ross respectively. Both design procedures are generalized for all centrifugal pumps but such conventional design is not suited for the design of very low specific speed pumps. As the losses insignificant in pumps of higher specific speed become more pronounced in lower specific speed pumps. Hence, in addition to the two design methods, various studies are done in the field of design of lower specific speed pumps and changes to the design were made accordingly. An Excel worksheet was made for the calculation of parameters which were then used for manual dimensioning of the impeller in CFTurbo. First, a design was made using the same blade curve of the existing impeller but higher outlet channel width and lower outer diameter. This was done so that the effect of change in impeller outlet channel width and reduction of outer diameter in the efficiency of the impeller could be studied, which would give us an idea of the scope of improvement with the existing casting. A second six vane design was developed with the same outer diameter and channel width as of the first design but the blade profile was changed so as to minimize the flow incidence angle and the flow deviation angle. Flow incidence and flow deviation angle for six vanes impeller were calculated with blade blockage in consideration and at different flow rates. **[2][3]**

1.4 Pump Efficiency

The specific work represents the energy transferred per unit mass, the **useful power** P_u of a pump is obtained by multiplying the transported mass flow $m=\rho \times Q$ by the specific work Y: $P_u = \rho YQ = \rho gqh = Q\Delta p$. The power P needed at the coupling is greater than the useful power because it includes all losses of the pump. The ratio of both values is the pump's efficiency η. The efficiency of pump depends not only on the specific speed, but also the pump type, design and absolute size. For extremely small pumps efficiencies are quite lower. **[2]**

1.5 NPSH

Net Positive Suction Head (NPSH) is what the pump needs, the minimum requirement to perform its duties. NPSH takes into consideration the suction piping and connections, the elevation and absolute pressure of the fluid in the suction piping, the velocity of the fluid and temperature. NPSH is the reason that the suction nozzle is generally larger than the discharge nozzle. If there is more liquid leaving the pump faster than the liquid can enter into the pump, then it may lead to cavitation. Net Positive Suction Head required is the minimum suction pressure head required at the inlet for the fluid to stay in liquid state. It is the characteristic of the pump. According to the standard of the Hydraulic institute, a suction lift test is performed on the pump and the pressure in the suction vessel is lowered to the point where the pump suffers 3% loss in total head. This point is called the NPSHr of the pump. It is determined by following formula: **[3]**

$NPSHr = ATM + P_{gs} + H_v - H_{vp}$

Where ATM = the atmospheric pressure at the elevation of the installation expressed in feet of head.

P_{gs} = the suction pressure gauge reading taken at the pump centreline and convert in to feet of head.

H_v = Velocity head = $V^2/2g$

Where V = the velocity of the fluid moving through the pipes

'g' = the acceleration of gravity.

H_{vp} = the vapour pressure of the fluid expressed in feet of head. The vapour pressure

1.6 Pump impeller

The pump impeller receives pump liquid and impart velocity to it with help from the electric motor, or driver. The impeller itself looks like a modified boats or airplane propeller. Actually both propellers are axial flow impellers, and also they are adapted to handle air. As general rule, the velocity (speed) of impeller and the diameter of the impeller, will determine the head or pressure that the pump can generate. As a general rule the velocity and height of the impeller blades will determine the flow that the pump can generate. Remember the pump cannot actually generate flow (no pump in the world can convert three gallon per minute at the suction nozzle into four gallons per minute out of the discharge nozzle), but this is the term used in industry. Pump designs have some different design characteristics. Among, this is the way where impeller received the liquid at the impellers ID. By centrifugal pump force and blade design, the liquid moves through the blades from the ID to the OD of the impeller where it expels the liquid in to the volute channel. **[1]**

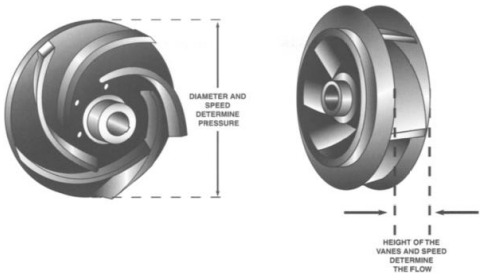

Fig.1 Pump Impeller

Problem Solution

- If the output head of the pump isn't sufficient, the head can be increased by under file impeller blade at outlet on suction side and increase channel width, b_2. The head can be reduced by decreasing impeller's outer diameter and decreasing the channel width, b_2.

2.1 Determination of main dimensions

The pump is designed for a flow rate Q =10 m^3/hr. and a head, H = 20 m. The speed of driving motor with the impeller angular speed is 2900 rpm. This corresponds to a specific speed, N_q = 16.2 m/ s and falls under the category of very low specific speed pumps. **[3]**

Specific Speed

Specific Speed N_s is a parameter used to characterize turbo machinery speed. In SI units it is defined as the speed in meter per second at which a geometrically similar impeller would operate if it were of such a size as to deliver one gallon per minute against one foot of hydraulic head. In SI units flow may be in m^3/s and head in m. Finding theoretically achievable efficiency, hydraulic efficiency, and ψ_{opt} is assumed as 0.95 by graph. **[3]**

The head coefficient

$$n_q = \frac{N*\sqrt{Q}}{H^{(\frac{3}{4})}} \qquad n_q = \frac{2900*\sqrt{(\frac{10}{3600})}}{(20)\text{^}(\frac{3}{4})}$$

$$n_q = 16.1612\ s^{-1}$$

The overall efficiency exponent

$$\mathrm{m} = 0.1\left(\frac{Q_{ref}}{Q}\right)^{0.15}\left(\frac{45}{n_q}\right)^{0.06}$$

$$\mathrm{m} = 0.257116336$$ (Where the *overall efficiency exponent* Q_{ref} = 1 m^3/s)

$$\eta_{opt} = 1 - 0.095(\frac{Q_{ref}}{Q})^{m} - 0.3\{(0.35 - \log_e \frac{n_q}{23})\}^2 (\frac{Q_{ref}}{Q})^{0.5} \quad , \quad \eta_{opt} = 0.466511$$

Theoretically achievable efficiency

$$\eta_{th,er} = \eta_{opt} + 0.035\left(\frac{Q_{ref}}{Q}\right)^{0.08}(1 - \eta_{opt}),$$

$$\eta_{th,er} = 0.765529$$

Hydraulic efficiency

$$\eta_{h,opt} = 1 - 0.055\left(\frac{Q_{ref}}{Q}\right)^{m} - 0.2\{(0.26 - \log_e \frac{n_q}{25})\}^2 \left(\frac{Q_{ref}}{Q}\right)^{0.1},$$

$$\eta_{h,opt} = 0.677392$$

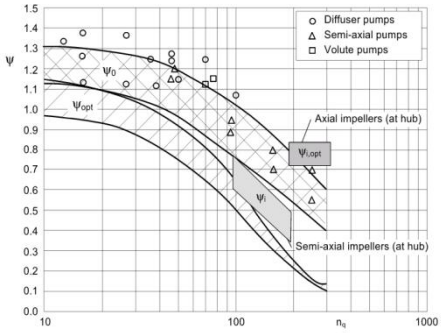

Fig. 2 Pressure coefficients

If ψ_{opt} is selected according to the upper curve in Fig. 2, rather flat characteristic are obtained. Therefore, the risk of an instability of the Q-H curve increases. The more so, the higher the value of ψ_{opt} is chosen. If a steep characteristic is required, ψ_{opt} is selected near the lower limit curve (or given below).

Impeller Outer Diameter

$$d_2 = \frac{84.6}{n}\sqrt{\frac{H_{opt}}{\psi_{opt}}}, \qquad d_2 = 127.318\ \mathrm{mm}$$

In order to achieve a stable Q-H curve, good part load behaviour and acceptably low hydraulic excitation forces, the head coefficient ψ_{opt} must be limited. Hence the lower value of 1.05 was chosen for design.

The previous design had an outer diameter of 156 mm which would result in a higher friction loss of 21.385%.

2.2 Blade Number

Two designs made were six and seven vane. The seven vane design was made keeping in view the efficiency gain over the six vane design as quoted in the paper 'Effects of Blade Number on Characteristics of Centrifugal Pump'. However, the six vane design was also made to avoid instability in the Q-H curve.

2.3 Impeller Inlet Diameter

The inlet Diameter, d_1 was chosen as 45.43 mm based on the standard inlet port size.
The hub diameter is also chosen as d_n =10.85 mm. The volumetric efficiency was assumed to be 100%
Thus giving a flow rate through impeller: Q_{La}=0.002777 m^3/hr

Channel Outlet Width

$$b_2{}^* = 0.017 + 0.262\left(\frac{n_q}{n_{q,ref}}\right) - 0.08\left(\frac{n_q}{n_{q,ref}}\right)^2 + 0.0093\left(\frac{n_q}{n_{q,ref}}\right)^3$$

Hence

$$b_2 = b_2{}^* \times d_2\,,\ b_2 = 0.007665\ m$$

Suction Specific Speed

$$n_{ss} = \frac{\mathrm{n}\sqrt{Q_{opt}/f_q}}{NPSH_{opt}{}^{0.75}}, \qquad n_{ss} = \frac{157.8\sqrt{\phi_{1opt}\,k_n}}{\sigma_{opt}{}^{0.75}}, \qquad n_{ss} = 41.8520\ s^{-1}$$

$$c_{1m} = \frac{Q}{f_q A_1} = 1.9165\ \frac{m}{s}, \quad c_{1u} = \frac{c_{1m}}{\tan\alpha} = -0.00121\ \frac{m}{s}$$

$$w_1 = \sqrt{c_{1m}{}^2 + (u_1 - c_{1u})^2} = 7.48152\ \frac{m}{s}$$

Flow coefficient

$$\phi_1 = \frac{c_{1m}}{u_1} = 0.265055 \qquad \beta_1 = \tan^{-1}\frac{c_{1m}}{u_1 - c_{1u}} = 0.259055\ rad \qquad \tau_1 = \left(1 - \frac{ze_1}{\Pi d_1 \sin\beta_{1B} \sin\lambda}\right)^{-1} = 1.719241,$$

$$\beta_1{}' = \tan^{-1}\frac{c_{1m}\tau_1}{u_1 - c_{1u}} = 0.427515\ rad$$

Blade Blockage

$$\tau_1 = \left(1 - \frac{ze_1}{\Pi d_1 \sin\beta_{1B} \sin\lambda}\right)^{-1}, \quad \tau_1 = 1.71$$

Where, z = 6, λ = 90 degrees, $e_1 = 4.34\ mm$, $\beta_{1B} = 24.6\ degrees$

Flow angle with blade blockage

$$\beta_1{}' = \tan^{-1}\frac{c_{1m}\tau_1}{u_1 - c_{1u}} = 0.427515\ rad$$

Incidence angle

$$i = \beta_{1B} - \beta_1^{'} = 0.09\ degrees$$

In the proposed design blade angle is almost equal to the flow angle giving nearly zero incidence. In the previous design the blade angle was 15° which indicates that blade blockage may not have been taken into

consideration while calculating incidence angle. (Flow angle without blade blockage for the original design is 14.84 degrees and blade angle 15°, therefore incidence may seem zero if no blade blockage is considered. But actual incidence angle with blade blockage was -24 degrees.). **[3]**

Meridional component of absolute velocity

$c_{2m} = \frac{Q}{f_q A_2}$ Where $f_q = 1\ for\ single\ entry\ pumps$

$A_2 = \pi \times d_2 \times b_2, \quad c_{2m} = 0.86\ \frac{m}{s}$

Circumferential component (c_{2u}) of absolute velocity is zero as no pre swirl is given.

Relative velocity

$w_2 = \sqrt{{c_{2m}}^2 + (u_2 - c_{2u})^2} = 2.79\ \frac{m}{s}$ Where, $u_2 = \frac{\Pi d_2 n}{60}$ = 20.32 m/s

Flow angle without blockage

$\beta_2 = \tan^{-1}\frac{c_{2m}}{u_2 - c_{2u}} = 0.32\ rad$

Blade blockage

$\tau_1 = (1 - \frac{z e_2}{\Pi d_2 \sin \beta_{2B} \sin \lambda})^{-1}, \tau_1 = 1.19$ Where, z = 6, λ = 90 °, $e_1 = 4.34\ mm, \beta_{2B} = 22\ degrees$

Flow angle with blade blockage

$$\beta_2' = \tan^{-1}\frac{c_{2m}\tau_2}{u_2 - c_{2u}} = 0.38\ rad$$

Table 1. Flow incidence and deviation angle for 6 Vane design at different operating points

Sr. No.	Flow Rate Number	Head Number	Deviation (outlet)°	Incidence angle (inflow)°	Specific speed (% by design)
1	10	20	0.528	0.092	100
2	9	21.4	0.196	2.290	90.17
3	8	22.5	0.293	4.558	81.88
4	7	23.5	0.438	6.894	74.13
5	11	18.5	0.439	-2.030	111.20
6	12	17	0.282	-4.077	123.74

Table 2. Flow incidence and deviation angle for 7 Vane design at different operating points

Sr. No.	Flow Rate Number	Head Number	Deviation (outlet)°	Incidence angle (inflow)°	Specific speed (% by design)
1	10	20	-0.096	1.360	100
2	9	21.4	-0.107	3.635	90.17
3	8	22.5	-0.120	5.992	81.88
4	7	23.5	-0.137	8.424	74.13
5	11	18.5	-0.087	-0.832	111.20
6	12	17	-0.080	-2.938	123.74

Slip Factor (γ)

$\varepsilon_{Lim} = e^{\frac{-8.16 \sin \beta_{2B}}{z}} = 0.60, \quad K_w = 1 - (\frac{{d_{1m}}^* - \varepsilon_{Lim}}{1 - \varepsilon_{Lim}})^3 = 1.23, \quad \gamma = f_1(1 - \frac{\sqrt{\sin \beta_{2B}}}{z^{0.7}})K_w = 0.99$

Deviation of outflow

$\delta_2 = \beta_{2B} - \beta_2 = 0.11\ degrees$

Slip Factor is 0.99 which indicates almost blade congruent flow. The previous design had a blade outlet angle of 29.5° giving deviation of 19.5°. Consequently its slip factor was 0.81.

Blade Thickness

Ideal blade thickness, e for an outer diameter d_2 is given by the relation,

$$\frac{e}{d_2} = 0.016\ to\ 0.022, \quad d_2 = 134\ mm\ given\ us, \quad e = 2.144\ to\ 2.948\ mm$$

2.4 Volute Casing

The pump's casing houses the hole assembly and protects is from harm, as well as forces the fluid to discharge from the pump and convert velocity into pressure. The casing of a centrifugal pump provides a pressure boundary for the pump and contains channels to properly direct the suction and discharge flow. The impeller is fitted inside the casing. The word volute actually describes a specific type of pump casing that converts energy created by the impeller into pressure. The impeller pushes water into the volute which converts that energy into pressure and directs the flow toward the discharge point. **[1]**

2.5 Turbo Machinery Design Software

CFturbo is a powerful software for interactive design of Turbo machinery. It is easy to use and enables the designer to either start from scratch or redesign existing geometries (reverse engineering). It guides the user through the required steps of the design process. A primary design is generated automatically, which can be influenced in each detail by the user. It includes several interfaces to established CAD- and CFD-packages and can optionally be extended by special functions according to the customer requirements. CFturbo contains a script solution for generating meshes for the designed geometry in ANSYS ICEM-CFD. **[4]**

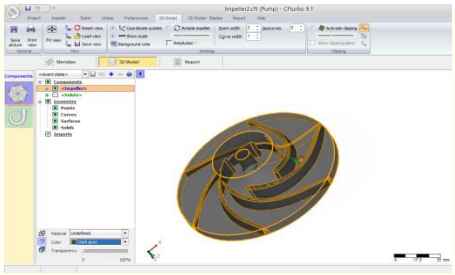

Fig. 3 Impeller development in CFturbo

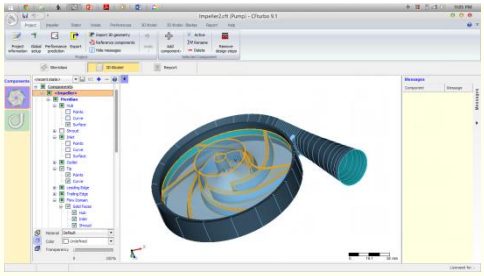

Fig. 4 Pump Design in CFturbo

2.6 Result and Summary of Work

The performance of the two impeller designs were predicted using CFTurbo 9.1 and are presented below. Although, it has to be noted that the curves are based on simple empirical estimation, deviation from design data is possible. In reality, experimental performance data of complete machinery stage or CFD result may differ from the values shown in above diagram. The following figures are at 2900 rpm. Also hydraulic resistance to flow changes the pump performance curve and has not been included in result.

Table 3. Compare analytical data and actual design data

Parameters	**Analytical Design**	**Actual Design**	**% Deviations**
Outside diameter	**156**	**127**	**29**
Eye Diameter	**47.6**	**45.43**	**2.17**
Hub Diameter	**18**	**10.85**	**7.15**
Channel Width	**2.5**	**7.75**	**5.25**

Number of Blades	**6**	**6**	**0**
Blade inlet angle	**15**	**14.79**	**0.21**
Blade outlet angle	**29.5**	**26.18**	**3.32**
Blade Thickness	**4.34**	**0.9**	**3.44**

An Impeller is always designed at a higher head than required to account for losses. Information was unavailable on the exact amount of additional head required and proposed designs are based on exact head required. Consequently a decrease in pressure head will be expected during testing (This does not imply that there will be loss in efficiency). An excel worksheet was made for pump parameters calculation based on user inputs. This was then used to model the two impeller designed a six vane and a seven vane impeller for CLC-40-2-2 series of pump.

Conclusion

Two designs of impeller have been proposed for CLC -40-2-2 pump. One design consists six blades while the other design consists seven blades. The blade inlet & outlet angle have been derived accordingly & rest of the design is same for both impellers. The hub diameter, inlet diameters & vane thickness do not have significant influence on impeller efficiency & have been kept the same as those in previous design to prevent extra machining cost. The blade development has been done in CFTurbo 9.1 and the rest of the parameters were calculated from graph and equations used. The meridional section of the impeller has not been changed. Maximum 123.74 percentage of specific speed would be got by using the head number 17 in 6 and 7 vane Radial Flow Centrifugal Pump. The impeller geometries were developed using CFTurbo by using manual dimensioning and the 6 number of blades are used. Here Radial Flow Centrifugal Pump is designed for the speed of 2900 rpm. The theoretical efficiency is 0.7655 and hydraulic efficiency is 0.6773 of this pump can be achieved. The designs have been presented for manufacturing and their performance curve will be experimentally determined and the more efficient design of the two with a suitable Q-H curve will be chosen for implementation.

Acknowledgements

The authors acknowledge the help provided by IDMC, Anand, till the completion with necessary guidance. We would also like to express our heartily gratitude to this industry for providing the opportunity to do this experimental work. Appreciations and special thanks to the industry resources for making the great effort to implement the technical knowledge in education.

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Traditional and TOPSIS based Failure Mode Effect and Criticality Analysis for Maintenance Planningof Aluminium Wire Rolling Mill Components

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Abstract

This paper highlights comparative results of traditional FMECA and multi-factor decision making approach based on "Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)" for aluminium wire rolling mill plant. The suggested study is carried out to overcome the limitations of FMECA by assigning the scores against each failure modes in crisp values to evaluate the criticalities of the failure modes without uncertainty. The primary findings of the paper is that sudden impact on the rolls seems to be most critical failure cause and high contact stresses due to rolling & sliding action of mesh to be least critical failure cause. It is suggested to modify the current control practices with proper maintenance strategy based on achieved maintainability criticality index (MCI). The outcome of study will be helpful in deriving optimized maintenance plan to maximize the performance of continuous process industry.

Key words **–** Reliability; Maintenance; FMECA; TOPSIS; Process Industry

1. Introduction

Reliability engineering is very important to maintenance personal. The application of it helps to identify the condition based faults in system, compare several possible failure patterns and prioritizing maintenance activities. Failure mode effect & criticality analysis (FMECA) is widely used tool to achieve this task. FMECA has two distinct analyses; FMEA and criticality analysis, where failure modes are ranked through risk priority number (RPN) by multiplying scores of criteria; detectability (D), probability of occurrence (P) and severity of effect (S). However, it considers only limited criteria like; D, Pand S, and does not cover some important criteria like; maintainability (M), spare parts availability (SP), economic safety (ES) and economic cost (EC), etc. which may also influence the failure modes. Moreover, same importance will be given to D, P and S ignoring their relative importance and even small variation in the value of D or P or S may changes in the value of RPN significantly due to multiplication rule. initially, traditional failure mode effect and criticality (FMECA) was carried out which is further extended to multi-criteria decision-making approach based on "Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)" method for calculation of Maintainability Criticality Index (MCI) in a view to overcome the limitations of FMECA.

Based on various literature reviews, it seems that many researchers have done various modifications for improvement of FMECA to overcome the drawbacks for different processing plants. Sahoo T. et al. [1] showed that Failure modes, effects and critique analysis (FMECA) is basic part of the maintenance plan and shows a strong tool to evaluate and improve system reliability with reduction of overall maintenance cost. Gilchrist [2] introduced economic considerations into his modified FMECA model while incorporating failure cost to form an expected cost model; Bevilacqua et al. [3] incorporated a new factor called operating conditions in the field of a power plant; Braglia [4] developed a new tool for reliability and failure mode analysis by integrating the conventional aspects of FMECA with economic consideration; and Sachdeva et al. [5] presented a multi-criteria decision-making approach to prioritize failure modes for paper industry using TOPSIS. Braglia et al. [6 – 7] presented fuzzy TOPSIS and Xu et al. [8] presented FMEA of engine system based on fussy assessment concept.

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Gargama and Chaturvedi [9] presented risk factors in fuzzy linguistic variables to generate fuzzy rank priority number. Adhikary& Bose [10] presented

multi-factor FMECA through COPRAS-G method for coal fired thermal power. Fenglin Zhang [11] deduced closeness coefficient for failure modes byintegrating both subjective and objective weights to avoid over or under estimation though fuzzy TOPSIS. Chanamool and Naenna [12] highlighted the importance of Fuzzy FMEA to prioritize and assess failures associated with working process of hospital's emergency department. Liu et al. [13] presented application of fuzzy analytic hierarchy process and entropy method in fuzzy VIKOR to assign weights to risk factor to avoid uncertainty and vagueness of subjective perception and experience.Maniya K. D. and Bhatt M. G. [14] presented multi-criteria decision making methodto solve problems of facility layout design selection based on preference selection index (PSI) method.

2. TOPSIS Methodology

TOPSIS is a multi attributes decision making system based on the measurement of Euclidean distance of each criterion from ideal value which was first discussed in crisp version by Hwang and Yoon [15]. Step by step procedure as discussed by Sachdeva et al. [5] is as under:

(i) Generation of decision matrix X:

$$X = [xij] \quad (1)$$

where; ith alternative – failure modes (i = 1, 2,….., n) is evaluated for jth criteria – (j = 1, 2,….., m)

(ii) Decision matrix normalization– X:

Normalizingdecision matrix by equation as follows:

$$rij = \frac{xij}{\sum_{i=1}^{n} xij} \quad (2)$$

(iii) Selection of positive and negative ideal solutions$s^{+} and\ s^{-}$respectively for each criteria:

$$s^{+} = [\max(ri1), \max(ri2), \max(ri3), \dots, \max(rin)] = (s1^{+}, s2^{+}, s3^{+}, \dots, sn^{+}) \quad (3)$$

$$s^{-} = [\min(ri1), \min(ri2), \min(ri3), \dots, \min(rin)] = (s1^{-}, s2^{-}, s3^{-}, \dots, sn^{-}) \quad (4)$$

(iv) Calculation of weights for each criteria

Initially entropy is calculated for each criterion as per following equation;

$$ej = -\frac{1}{\ln n} \sum_{i=1}^{n} rij \ln rij \quad (5)$$

Then, weight is calculated as follows;

$$wj = \frac{1 - ej}{\sum_{j=1}^{m} (1 - ej)} \quad (6)$$

(v) Calculation of distance between positive and negative ideal solution $di^{+} and\ di^{-}$respectively as following equations:

$$di^{+} = \sqrt{\sum_{j=1}^{m} wj\,(sj^{+} - rij)^2} \quad (7)$$

$$di^{-} = \sqrt{\sum_{j=1}^{m} wj\,(rij - sj^{-})^2} \quad (8)$$

where; i = 1,2,…..,n and j = 1, 2,…..,m

(vi) Calculation of Maintainability Criticality Index $MCItopsis$

$$MCItopsis = \frac{di^-}{di^+ + di^-} \quad (9)$$

Where; $MCItopsis$ are maintainability criticality index

3. Case Study

3.1 Introduction

The traditional and TOPSIS based model is applied to the critical components of aluminium wire rolling mill situated in Ahmedabad, India. The detailed layout of plant is given in Figure 1. The aluminium wire is produced through Properzi Process where, solid aluminium bar of 40 mm is fed into stands to gradually reduce diameter to 6 mm rod through fifteen stands in series. At each stand diameter of rod decreases by about 15-20%. The bearings, gears and shafts are considered as most critical components based on historical comprehensive failure and repair data.

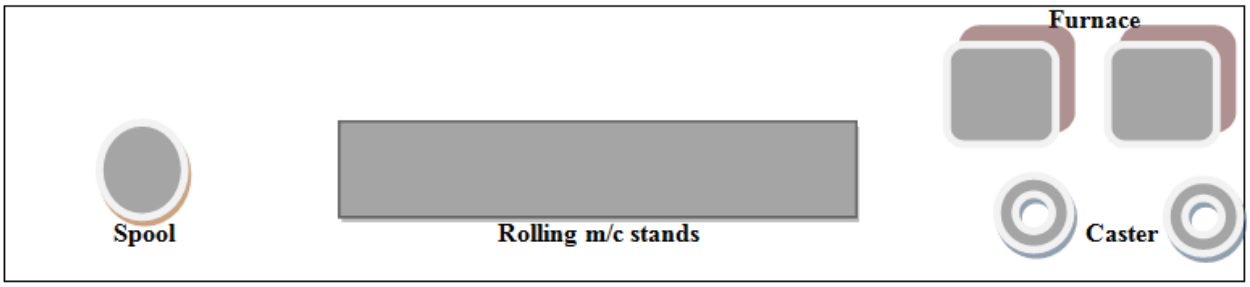

Fig: 1 Rolling Mill Plant Layout

3.2Assignment of Scores to Each Failure Mode

We considered the following methods to decide the score for each individual failure mode for every process input of critical components:

(i) Historical failure data; which gives comprehensive behavioral study of failure pattern of critical components
(ii) Questionnaires; to floor operators, managers, maintenance personnel

The scores for each failure cause for every different criterion are ranked on a scale of 1 – 10. The scale of 1 to 10 refers from least to most consideration of the impact of criteria. The scores for probability of occurrence (P), degree of detectability (D),) and severity (S) are shown in Table 1, Table 2 and Table 3 respectively for traditional FMECA. The scores for chances of failure (P), degree of detectability (D), degree of maintainability (M), spare parts (SP), economic safety (ES) and economic cost (EC) for various failure causes are as per Table1, Table 2, Table 4, Table 5, Table 6 and Table 7 respectivelyin crisp values for TOPSIS.

During a brainstorming session, maintenance personnel scores a criticality factor into different criticality levels so it challenging to do criticality analysis of failure modes accurately. Hence this practical difficulty can be solving by expressing the scores of a criticality factor in exact crisp value (TOPSIS) with addition of some more important criteria. The main idea of TOPSIS model is to overcome the limitations of traditional FMECA.

Table 1 Scores for probability of occurrence (P)

Occurrence	Criteria for occurrence	Score
Almost never	More than three year	1
Very Rare	Once every 2-3 year	2
Rare	Once every 1-2 year	3
Very Low	Once every 11-12 month	4

Low	Once every 9-10 month	5
Medium	Once every 7-8 month	6
Moderate High	Once every 5-6 month	7
High	Once every 3-4 month	8
Very High	Once every 1-2 month	9
Extremely High	Less than 1 month	10

Table 2 Scores for detection of failure (D)

Chances of detection	Likelihood of Non detection (%)	Score
Immediate	< 10	1
Best	10 to 20	2
Better	21 to 30	3
Good	31 to 40	4
Easy	41 to 50	5
Occasional	51 to 60	6
Late	61 to 70	7
Difficult	71 to 80	8
Very Difficult	81 to 90	9
Impossible	91 to 100	10

Table 3 Scores for severity (S)

Effect of severity	Service duration affected	Score
Almost nil	< 30 min.	1
Very rare	1 hour	2
Rare	2 hour	3
Very Low	3 hour	4
Low	4 hour	5
Medium	5 hour	6
Moderate High	6 hour	7
High	7 hour	8
Very High	8 hour	9
Extremely High	>8 hour	10

Table 4 Scores for maintainability (M)

Chances of detection	Likelihood of Non detection (%)	Score
Extremely High	< 10	1
Very High	10 to 20	2
High	21 to 30	3
Moderate High	31 to 40	4
Medium	41 to 50	5
Low	51 to 60	6
Very Low	61 to 70	7
Rare	71 to 80	8
Very Rare	81 to 90	9
Almost Nil	91 to 100	10

Table 5 Scores for spare parts (SP)

Criteria for availability and requirement	Score
Easily available & Desirable	1
Easily available & Essential	2
Easily available & Very essential	3
Hard to procure but Desirable	4
Hard to procure but Essential	5
Hard to procure but Very essential	6
Scarce and Desirable	7
Scarce and Essential	8
Scarce and Very essential	9
Impossible and Urgent	10

Table 6 Scores for economic safety (ES)

Criteria for economic safety	Score
Extremely low	1
Very low	2
Low	3
Fair	4
Average	5
Medium	6
Moderately high	7
High	8
Very high	9
Extremely high	10

Table 7 Scores for economic cost (EC)

Criteria for economic cost	Score
Extremely low	1
Very low	2
Low	3
Fair	4
Average	5
Medium	6
Moderately high	7
High	8
Very high	9
Extremely high	10

3.3 Maintenance Planning through Traditional FMECA

Based on achieved RPN and analysis of existing maintenance strategies; revised and effective maintenance methodology has been suggested as displayed in Table 8. Looking to the outcome of traditional FMECA; Failure modes with RPN more than 500 are considered most critical and required to perform predictive maintenance, RPN from 250 to 500 are considered critical and recommended preventive maintenance and less than 250 are considered normal failures which are recommended corrective maintenance.

3.3Maintenance Planning through TOPSIS based FMECA

We calculated maintainability criticality index ($MCItopsis$) for each failure cause based on procedure as discussed in section – 2. Table 8 shows maintenance planning through MCDM based FMECA approaches.

It has been observed from the Table 8 that bearing misalignment and improper mounting (C5) seems to be most critical failure cause and Gear teeth surface cold/plastic flow (C11) seems to be least critical failure cause. It is suggested to modify the current control practices as listed in Table 8 that failure causes (C5, C3, C1, C10, C14) with large value of $MCItopsis$ should be kept under predictive maintenance, failure cause (C4, C6, C13, C8, C7) with moderate value of $MCItopsis$ should be kept under preventive maintenance and failure causes (C2, C9, C12, C11) with low $MCItopsis$ should be kept under corrective maintenance.

Table 8 Maintenance planning through traditional as well as TOPSIS approach

Particulars				Current Controls	Standard FMECA					TOPSIS FMECA							
Key Process Input	Potential Failure Mode	Potential Causes	Potential Failure Effects		D	P	S	Risk Priority Number	Rank	P	D	M	SP	ES	EC	Maintainability Criticality Index	Rank
What is the Process Input?	In what ways can the Process Input fail?	What causes the Key Input to go wrong?	What is the impact on the Key Output Variables once it fails (customer or internal requirements)?	What are the existing controls and procedures that prevent either the Cause or the Failure Mode?	How well can you detect the Cause or the Failure Mode?	How often does cause or FM occur?	How Severe is the effect to the customer?			Chance of failure	Detection probability of failure	Maintainability criteria	Spare parts criteria	Economic safety criteria	Economic cost criteria		
Rolling Mill Bearing Failure	Bearing high temperature	Improper lubrication & defective sealing	Bearing gets jammed/Bearing housing jammed	Lubricating the parts when occurred	8	5	7	280	7	9	8	1	3	3	3	0.7095	9
	Bearing corrosion	Higher speed than specified	Increase in vibration & noise	Proper coolant	6	3	4	72	12	8	6	2	2	4	3	0.4265	10
	Bearing fatigue	Design defects, Bearing dimension not as per specification	Life reduction	Bearing replacement	7	9	10	630	1	10	7	6	3	10	9	0.3640	2
	Roller balls wear- out	Foreign matters/particles	Sudden rise in thrust	Regular cleaning of parts	6	8	7	336	4	9	6	5	3	7	5	0.7986	3
	Bearing misalignment & improper mounting	Sudden impact on the rolls	Shaft damage & Impact damage on other parts	Routine check up	5	8	8	320	5	10	5	6	5	9	10	0.5794	1

	Electrical damage	Loss of power	Operation interrupted	Electrical wiring check up	1	2	7	14	14	9	1	1	3	5	2	0.8051	14
	Gear teeth wear-out	Inadequate lubrication - Dirt, viscosity issues	Rough operation & considerable noise	Routine check-up of lubrication	2	5	5	50	13	7	3	5	3	7	4	0.2499	8
	Gear teeth surface fatigue (Pitting)	Improper meshing, case depth & high residual stresses	Gear life reduction	Preventive maintenance	5	8	8	320	6	8	5	5	3	5	5	0.4419	7
Rolling Mill Gearing Failure	Gear teeth scoring	Overheating at gear mesh	Interference & backlash phenomenon	Lubricating when needed	6	7	4	168	9	5	4	2	3	3	3	0.4981	13
	Gear teeth fracture	Excessive overload & cyclic stresses	Sudden stoppage of process plant	Break down maintenance	6	8	8	384	3	9	2	6	4	7	7	0.2515	4
	Gear teeth surface cold/plastic flow	High contact stresses due to rolling & sliding action of mesh	Slippage & power lose	Gear replace when needed	3	5	5	75	11	3	6	3	3	3	3	0.5636	12
	Shaft fretting	Vibratory dynamic load from bearing	Leads to sudden failure	Break down maintenance	6	5	5	150	10	5	5	4	3	3	3	0.3460	11
Rolling Mill Shaft (Primary & Secondary) Failure	Shaft misalignment	Uneven bearing load	Vibration & fatigue	Preventive maintenance	7	7	8	392	2	8	5	5	3	6	6	0.3525	5
	Shaft fracture (Fatigue)	Reverse & repeated cyclic loading	Sudden stoppage of process	Preventive maintenance	4	7	8	224	8	9	2	6	4	6	7	0.5505	6

4. Results and Discussion

It is noticed from the failure pattern that 70 % down time is due to bearing failure and replacement practice is 100 %, so it is recommended to select standardize bearing with appropriate specifications and mount them properly during every replacement to avoid bearing misalignment (C5) and minimizing reverse and repeated cyclic loading thus shaft fatigue (C14) and gear tooth fracture (C10) can be avoided. Appropriate condition monitoring is suggested to continuously record the condition of bearing damage and shaft damage to prevent sudden breakdown and starting thrust on these components. Also, the condition of lubricants should be checked and replaced whenever necessary rather than routine clean up. Hence, sudden impact on the rolls (C5), design defects with bearing dimension/specification(C3), foreign matters/particles (C4), excessive overload & cyclic stresses (C10) and reverse & repeated cyclic loading (C14) can be covered under recommendations. Failure causes with moderate and low $MCItopsis$ are controlled under preventive and corrective maintenance practices.

Table 9 shows the comparison of priority of maintenance activities to be carried out to each failure causeobtained through both approaches discussed in this paper.The maintenance planning is based on understanding and evaluating criticalities of different failure modes of each critical component. The traditional FMECA method is proposed only C3 as most critical failure mode whereas MCDM based TOPSIS proposed more failure modes (C5, C3, C1, C10, C14) as critical. It is important to identify the critical failure modes for remedial measures and effective maintenance actions. The outcome of research study clearly shows the importance of multi-criteria approach over traditional approach in maintenance planning of identified process industry.

Table 9 Results comparison for traditional versus TOPSIS FMECA

	Method	Result Analysis		
1	Traditional FMECA	Most Critical (RPN: > 500)	Critical (RPN: 250 < RPN < 500)	Normal (RPN: < 250)
		C3	C13, C10, C4, C5, C8, C1	C14, C9, C12, C11, C2, C7, C6
2	TOPSIS Model	High MCI	Moderate MCI	Low MCI
		C5, C3, C1, C10, C14	C4, C6, C13, C8, C7	C2, C9, C12, C11

5. Conclusion and Scope

This paper discuss the traditional FMECA approach dealing the different failure modes of critical components of aluminium wire rolling mill and appropriate maintenance plan was suggested based on RPN achieved from the scores assigned as per criteria. Moreover modified FMECA approach based on TOPSIS is also proposed to overcome the limitations of FMECA by considering more criteria in crisp value. Comparative study presented in this paper, clearly shows how TOPSIS based FMECA works on each failure modes accurately with making multi-criteria approach over traditional FMECA.

The proposed study is challenging and interdisciplinary work; it will help to understand about the working lives of components and associated failures, which lead to reengineer new technologies efficiently and to gain the operational advantage. We concluded that the study will be helpful in designing optimized maintenance plan to improve plant efficiency as a whole. The similar work can be extended to process industries of different kinds in a view to deciding suitable maintenance strategy.

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Biofuel for CI Engine: A Review on Engine Emission

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Abstract

Alternatively petroleum for compression ignition (CI) Engine, biofuels are in main alternative and neutral carbon content. However, their use increases technical, environmental and economical issues. A full technical review on the utilization of biofuel (pure oil/blend with diesel/blend with diesel in the occurrence of additives) in compression ignition engines predicated on performance and emission comparisons with mineral diesel fuel is completed in this work. It is really discovered that biofuel appears to be a great option to greatly reduce environmental emissions. Although nearly all biofuels can be utilized in compression ignition engine unit with no improvements, change in operating guidelines (Biofuel, Injection pressure, Injection timing, & compression ratio) is highly recommended for improvement in performance of engine. Moreover, small time engine run studies also show that biofuels have great potential to displace conventional mineral diesel.

Keywords: CI Engine, Biofuel, NOx, HC.

Nomenclature

CA	*crank angle*
CR	*compression ratio*
CIDI	*compression ignition direct injection*
CO	*carbon monoxide*
CO_2	*carbon dioxide*
CR	*compression ratio*
DI	*direct injection*
NOx	*nitrogen oxide*
SD	*smoke density*
PM	*particulate matter*
EGT	*exhaust gas temperature*

Introduction

The world's budget rely on the utilization of fossil energy which is estimated to the consumption of 946 lacks barrels of petroleum every day [1]. The consumption rate of yearly burning fuel rate is equivalent to what environment takes around one million years to store as fossil deposits. The globe at current, is challenged with the lowering of twin crises of fossil energy and environmental degradation. Promiscuous removal and excessive ingestion of fossil fuels have resulted in minimizing underground-based carbon capitals. The search for an alternative oil, which guarantees an enjoyable relationship with sustainable development, energy saving, management, efficiency, and ecological safeguard, is becoming proclaimed in today's platform extremely. It really is interesting to notice that, more than 65 lacks diesel motors are existing in the Indian farming area for numerous activities. It is really difficult to acquire an alternative for diesel machines and hence fuels of required choice are being expeditiously required. So far as the application is concerned in agricultural regions of a growing country like India can be involved, such IC engine must utilize substitute fuels of bio-origin ideally, which are locally existing. This permits the replacement of diesel fuel by plant oils, as well as for a short-range fuel as a combination.

Biofuel is used as a cleaner fuel as compared to that of petroleum or mineral diesel fuel. While by using a different fuel, it's very essential to balance equilibrium among several conflicting constraints affecting not only the performance and emission characteristics of the IC engine, but also the entire life of the machine [2].

Amongst all the tests done for the choice fuels, it is discovered that bio-diesel, created from alternative and local options often, presents a far more lasting way to obtain energy and can, therefore, play an extremely significant role in providing the requirements for transport.

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Nearly all studies show that PM, CO_2, unburned hydrocarbons and CO emissions for bio-diesel are reduced significantly, weighed against diesel. Experiments also conclude that the utilization of bio-diesel reduces carbon deposits and wear of the key engine parts as compared to diesel [2].

Effect of biofuel on engine emission

The review on the effect of biofuels on IC engine emissions i.e., CO, CO_2, NOx, and HC is shown in Table 1. The evaluations in Table 1 show that the CO_2 emission from engine unit fuelled with biofuels is lower when compared with mineral diesel oil, and, CO and HC emission is also lower with available biofuels [7,8]. The availability of oxygen in biofuel causes enhancement in the combustion which is the key reason behind the decrease in HC and CO emission. Because of the same reasons, it is seen that NOx emissions are reduced in case of biofuel. The addition of oxygenated chemicals along with biodiesel is a straightforward and most encouraging option to reduce CI engine emission [8,9]. Various experts [3,7,10] reported that the biodiesel (20 percent) with some chemicals offered the best performance and decrease in exhaust emission including NOx. They figured additives are great oxygenated fuels which improve exhaust characteristics of the CI engine.

Effect of engine operating parameters on engine emission

As per previous discussion, the fuel containing oxygen can be substituted with the petroleum diesel without the changes in diesel engine. For the engine unit fuelled with the mixes of diesel and biodiesel, it is more essential to understand the variables that impact its performance, combustion and emission characteristics that will have a primary effect on thermal efficiency. It is observed that engine parameters such as injection timing, compression ratio, and injection pressure have a significant influence on performance and emission of the diesel engine running on diesel and biodiesel blends. Many experts have reported the after effect of diesel engine running on biodiesel and design variables like Injection pressure, Injection timing, and compression ratio.

3.1 Effect of injection timing on engine emission

To run a CI engine, oil injection timing is a significant parameter that influences the emission. The condition of air into that the required oil is injected which changes the injection timing and so ignition delay varies. Research workers have tried different kinds of plant natural oils with different injection timing and then did the comparison of the diesel engine emission with fossil diesel. Due to the strange properties of bio oil, the characteristics of atomization and combustion have a tendency to fluctuate. The literature shows significant performance variation in emission among different kinds of plant oils with little modified in injection timing: shown in Tables 2 respectively. The biofuels have a lower volatility and increased flash point. Furthermore, the delay period of biofuels and its own mixes are higher when compared with mineral diesel. Because of lower volatility and higher delay period, various analysts [11-15] have recommended advancing injection timing when an engine is fuelled with biofuel / mixes. Further, the research workers [11,15,16] also have advised to retard timing of injection when high cetane quantity oxygenated additives are being used combined with the mixes of biofuel. That is because of the fact that the utilization of oxygenated chemicals reduces period of delay and increased premixed combustion period. It is noticed that, while changing the injections timing the performance of engine unit somewhat deteriorated with large decrease in various engine emissions as reported in Table 2 respectively.

3.2 Effect of injection pressure on engine emission

Nowadays higher injection pressures are obtained by the newly designed fuel injection systems. Its main aim is to increase the efficiency by decreasing exhaust emissions of the diesel engines [6]. The main cause of fuel ignition delay is due to low pressure of fuel injection, as a result of which diameter of particles of fuel increase and cause the delay. Hence there is an increase in pressure due to poor combustion which in turn causes the engine performance to be hampered, mixing of fuel to air causes better ignition and engine performance automatically synchronises. The higher the injection pressure shorter the delay period [9-12]. This decreases the possibility of homogenous mixing and combustion efficiency also decreases. Pressure generation depends on the engine size and area of application and hence the pressure generated is between 1000 to 2000 Bar.

It is known that the pressure required to inject the fuel in the cylinder is called Injection pressure, and for combustion to be normal cylinder pressure should be lower than injection pressure .If the injection pressure is

higher than the fuel is dispersed and penetrated uniformly in the combustion chamber. For complete combustion of the fuel, mixing of intake gas and the fuel should be more uniform and subsequently higher injection pressure is required. The requirement of higher injection pressure in CI engine is due to the higher viscosity and poor atomization of biodiesel. The amount of hydrocarbon emission can be effectively controlled by increasing the injection pressure as mentioned in table 3.

3.3 Effect of compression ratio on engine emission

Compression ratio is the percentage of swept volume to clearance volume. The in-cylinder temp and pressure rises with upsurge in compression percentage. Such upsurge in in-cylinder temperature and pressure results better mixing of fuel and air, better atomization and decrease in delay period and better combustion with ultimately giving an efficient and even working of the engine unit. Though the self-ignition temperature of biodiesel is quite high as compared to that of mineral diesel, but still it can be enhanced more through higher compression ratio. Thus, a lot of the researchers have recommended increasing compression proportion when a CI engine is fuelled by biodiesel or other oxygenated chemicals [14,20-24]. The result of compression percentage on CI engine emission and performance are shown in Table 4.

Further, scheduled to improvement in combustion quality, the HC and brake specific fuel consumption found to be lower with increasing CR [21]. It ought to be noted that NOx emission is available to be higher due to increasing in in-cylinder temperature and pressure with a rise in CR [20-23].

Table 1. Effect of biodiesel and additives on engine emission parameters.

Sr No	Fuel used	Engine Specification and adjustments/ work conducted	SD(Smoke)	HC	NOx	Ref
1	Rapeseed biodiesel	Air cooled engine with No modification	n/a	Rises	Decreases	5
2	3 diesel-DMM blended fuels containing 20%, 30% and 50% by v.v fraction of DMM	1 cylinder, direct injection diesel engine, Inline -nozzle, Cooling liquid temperature varied from 80.0–85.0 °C while the lubricating oil temperature varied from 90.0–100.0 °C and the engine running steadily	Decrease smoke Emissions	Rise HC emission	Exhaust gas recirculation decreases NOx Emissions	4
3	Mineral Diesel: sunflower biodiesel (50:50)	1 cylinder, 3.6 kW @1500 rpm Fuel inlet temperature 5.0 °C	Decreases to 11.4%	19.6% decreases	45.5% decreases	9
4	Mineral Diesel:Jatropha biodiesel	Diesel engine, 6.0 HP, Air cooled engine Constant speed, run @220 bar	25.7% decreases	Decreases to 33.2%	Decreases to 34.0%	10
5	Mineral Diesel:karanja biodiesel	4 stoke, 1 cylinder, air cooled diesel engine	Decreases	Rises	Rises 3.4% to 28.19%	6
6	Biodiesel (20%)–DEE(4%)	4 stoke, single cylinder CI engine	Decreases with diesel	45.4% lower compare to diesel	15.6% lower than the diesel	25
7	Biodiesel (20%)–Additives (1%)	4 stoke, single cylinder, water cooled diesel engine	12% decreases	20% reduction compare to diesel	Decreases with B20+1% additives	28

Table 2. Effect of injection timing on engine emission parameters.

Sr No	Fuel used	Injection timing	CO	HC	NOx	Ref
1	Plastic Oil from waste	Delayed from 23.0^0 to 14.0^0 CA BTDC in interval of of 3.0^0	At no load and retarding condition CO decreases up to 19% and at full load condition further it increases up to 23.4%	At no load and retarding condition HC decreases up to 48.49% and at full load condition further it decreases up to 22.79%	At no load and retarding condition NOx decrease up to 46.39% and at full load condition further it decreases up to 58.8%	11
2	Ethanol blended mineral diesel fuel from 0% to 15% with an addition of 5%	Advanced from 27.0–33.0° CA BTDC	At advancement of injection timing while maximizing the percentage of ethanol causes the decrease in CO up to 10%	At advancement of injection timing 6.0° CA BTDC and at Ethanol 5% fuel causes 18.0% decrease in HC	Accumulation of Nox emission rises as the ethanol percentage increase in the diesel blended fuel for all timing. Nox emission rises 46% for ethanol 0% when the injection timing at maximum.	13
3	Ultra-Low mineral diesel and Mineral diesel- Ethanol Blends	CA deduction	At advanced injection timing higher emission noted for all mineral diesel-biodiesel blends	At advanced injection timing rise in emission are noted significantly for all blends	At advanced injection timing Emission decrease	14
4	Mineral Diesel and Jatropha Bio Diesel	Modification from 34.0–35.0° CA BTDC	For all injection timing CO emission increased For Bio diesel At advancement of injection no difference fund but at retardation changes are found	Higher emission at advanced timing	NOx emission found high at advanced timing	15
5	Honge methyl Ester- mineral diesel blends B10,B15, B20 and B25	Retardation or advancement in injection timing by 3.0° CA BTDC	At improvement of injection timing, CO emission decreases by 20.0% for B20 blend	At advancement of injection timing, HC emission decreased by 10.0% for B20 blend	At delay of injection timing NOx emission decreases by 4.7% for B20 blend	16

Table 3. Effect of injection pressure on engine emission parameters.

Sr No	Fuel used	Injection pressure	CO	HC	NOx	Ref
1	Karanja based Bio diesel – mineral Diesel Blend B10 and B20	Increase in Injection pressure from 460.0 bar to 480.0 bar	Decreased emission	Decreased emission	NOx emission rises at higher injection pressure	6
2	Cardonol biodiesel (20%)- Methanol (10%) – Mineral diesel(70%) Blend	Increase in Injection pressure from 180.0 to 220.0 bar in stage of 20.0 bar	Decreased up to 57.0 % at higher injection pressure	Decreases up to 69.0 % at higher injection pressure	NOx emission rises up to 11.0 % at higher injection pressure	12
3	Jatropha biodiesel & Rubeer Seed Biodiesel –Mineral diesel Blend	Higher in Injection pressure from 200.0 to 240.0 bar in stage of 20.0 bar	Decreased up to 10.0 % at higher injection pressure	Decreases up to 7.5 % at higher injection pressure	Increased Emission at Higher injection pressure	17
4	Biodiesel oil – Mineral diesel Blend B5, B20, B50 and B100 based blends	Higher in Injection pressure from 18.0 to 24.0 Mpa in stage of 2.0 MPa	Decreased up to 9.0 % at higher injection pressure	Decreases up to 9.4 % at higher injection pressure	Higher NOx at high percentage biodiesel at high injection pressure	18

5	Discarded cooking oil biodiesel	Range from 220.0 bar to 300.0 bar in stage of 20.0 bar	-	-	NOx emission decreases 7.% at higher injection pressure (280.0 bar)	19

Table 4. Effect of compression ratio on engine emission parameters.

Sr No	Fuel used	Compression ratio	CO	HC	NOx	Ref
1	Used fried oil and Mineral diesel Blends B50 B70 B0-Mineral Diesel	CR 14.5 ,16.5 and 17.5	Higher the concentration of bio diesel (B70)with higher in Compression ratio (17.5) CO emission decreases	Higher the concentration of bio diesel (B70)with advancement in Compression ratio (17.5) HC emission reduced	Higher the concentration of bio diesel (B70) with high Compression ratio (17.5) NOx emission rises	20
2	Karanja – Mineral diesel Blend B10, B20, B30 and B50	CR 17.5, 17,7 17.9 and 18.1	At high CR HC decreases by 4 % at B30	At higher CR CO emission reduced by 37.09 % at B30	At higher CR Nox emission rises by 10.0 % at B30	21
3	Jatropha biodiesel methyl ester	B100 CR varies between 16 to 18	At high CR CO emission rises by 10.0 % -B100	at advanced CR HC emission reduced by 50 %	At higher CR Nox emission rises by 25.0 %	22
4	Used cooking methyl ester and Mineral diesel Blends B20, B40 , B60 and B80	CR 21	No change compare to mineral diesel fuel	HC emission lower by 23 %	Nox emission less with B40	23
5	Ester of Thevetia Peruviana seed oil- Mineral diesel blend (B20)	CR varies between 14.5 to 20.6	Decreases of 33.3% at higher CR	Decreases 27.2% at advanced CR	Decreases 10.29% at higher CR	24

Conclusion

This review article mainly targets on the analysis on the life cycle of the engines using pure or blended plant oils. An assessment of paperwork has disclosed that, with contrast to mineral diesel, exhaust emission of CO_2 are regular with biodiesel oil but NOx emission decreases in the case of biodiesel. Experiments performed by researchers reveal that there is a fluctuation in performance engine and difficulties like deposition of carbon, dilution of lubrication oil or CI engine oil thickening, sticking of piston diamond cut ring and choking of fuel injector nozzle. To overcome this difficulty, pre-heating of biofuel, mixing with diesel, trans-esterification of the natural source oils has been attempted to improve emission in CI engine. Some alterations to engines formulated with improving or reducing injection timing and injection pressure of nozzle is also mentioned in this paper.

1) Effect of Injection Timing on Engine Emission: There should be high rate of injection timinig due to low volatility and high delay period in case of biofuels and the injection timing should be retarded in the case of low cetane properties in the biodiesel.
2) Effect of increase in Pressure on Engine Emission: Due to higher viscosity and poor atomization of biodiesel, it is reported that higher injection pressure is required with the use of biodiesel in CI engine.
3) Effect of Compression Ratio on Engine Emission: Though the oxygen content increases combustion rate but due to less volatility of fuel a higher compression ratio is required, but for enhancing the performance and emission level of CI engine oxygenated additives are used.

However, it can be finally concluded that biodiesel can be a substitute option for the CI engine till any other further improvement or alterations.

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A review on active solar stills coupled with evacuated tube collector

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Abstract

Water scarcity is the major challenge for the world today. Many arid areas are suffering from water scarcity. Number of researchers are contributing to find out the alternatives to produce drinkable water in arid areas economically. For the same, use of renewable energy sources is the research trend nowadays. Solar energy is the easiest and accessible source available to human kind. Solar stills are the devices which are proved to be fruitful to produce drinkable water in remote areas. Novel designs and modifications are done to the conventional solar still in order to increase the yield of a solar still. Use of external collectors (active solar still) of different types with natural and forced circulation of heat transfer fluids, thermal storage media, heat absorption improving materials like dye have been experimented by various researchers. Due to higher efficiency, Evacuated Tube Collectors (ETC) are now widely used and have substituted Flat Plate Collectors (FPC) for many applications including solar distillation systems. This paper aims at detailed review of different studies on active solar still coupled with ETC in natural as well as forced circulation mode. Yield and efficiency are compared for different studies.

Keywords: Active solar still, Evacuated Glass Tube (ETC), Natural circulation, Forced circulation.

1. Introduction

Water is one of the basic needs of human kind. It is well known fact that 97% of water available on earth is in the oceans and the remaining proportions of water are in the form of ice, groundwater, lakes and rivers. Only less than 1% of the available water is fresh and accessible to human. According to World Population Prospects 2015 [1], population of world has reached to 7.3 billion in 2015, which is expected to reach 8.5, 9.7 and 11.2 billion respectively in the year of 2030, 2050 and 2100. India has second largest population now and is expected to overcome china for first position by 2025. As the population grows demand for fresh water will also grow. According to Falkernmark Water Stress Indicator, a country is said 'water stressed' if water availability falls below 1700 m^3 per person per year and is said 'water scarce' if water availability falls below 1000 m^3 per person per year [2]. UN reports predict that 3.4 billion people will live in 'water scarce' countries by 2025. It also predicts India as the country which will be most influenced to this shortage. India has per capita water availability of 1525 m^3/annum which is expected to fall below 1000 m^3/annum after 2030. Thus India is already 'water stressed' and soon will be 'water scarce' country. Hence there is a strong need of alternate source of water for survival of India and World.

Desalination is the possible way to meet the requirement of water. It is a process of separating excessively dissolved salts from brackish and seawater, in order to collect low salted-water for any suitable use such as drinking, industrial, pharmaceutical or household water. It works on principle of nature i.e. evaporation and condensation. Raining is a natural example of desalination process. Brackish or seawater gets vaporized as it is heated by the sun, and it gets condensed when temperature is below due-point temperature. For desalination, mainly two energy techniques are available i.e. Thermal and Electrical. Solar desalination (SD), Humidification-dehumidification (HD), Membrane distillation (MD), Multiple effect distillation (MED), Multistage Flash distillation (MSF), Vapor Compression (VC) are thermally driven desalination processes while Reverse Osmosis (RO), Electro-dialysis (ED), Mechanical Vapor Compression (MVC) are electrically driven desalination processes [3,4]. Among these different methods, one which uses partly or entirely renewable energy sources is said to be fruitful. Solar Desalination is one of the processes which uses solar energy available in enormous amount.

Solar thermal desalination is preferred for remote area, have comparatively low water requirements, have cost constraints and lack of availability of fossil fuels.

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Basically, solar thermal desalination can be carried out in two ways i.e. direct and indirect [5]. Solar still and solar pond use solar energy directly while Multistage Flash distillation (MSF), Multiple Effect Distillation (MED), Membrane Distillation (MD) are examples of indirect solar desalination. Solar stills are simple in construction and require less investment compared to other processes.

Solar still can be classified into two types viz. passive and active solar still. Passive solar still contains only conventional basin part for evaporation and condensation process. Whereas in active solar still conventional basin is connected with solar collector to enhance the temperature rise in water. Different types of collector viz. Flat Plate Collector (FPC), Concentric Parabolic Collector (CPC), Evacuated Tube Collectors (ETC), etc. are used with conventional solar still. ETC is proved to be most suitable collector compared to other ones due to its unique construction which prevents convection losses. Active solar still can further be classified into two types viz. active solar still with natural circulation and with forced circulation. This paper presents a review of different work carried out on active solar still coupled with ETC.

2. Active solar still coupled with ETC with natural circulation mode

2.1 Active solar still coupled with ETC with reflector

In this type of active solar still a parabolic or plane reflector is positioned below ETC to increase the aperture area and hence solar radiation falling on ETC.

2.1.1 Single basin active solar still coupled with ETC with reflector

Sampathkumar [6] developed a single slope active solar still coupled with ETC as shown in Fig. 1. Black gravel was used to increase the yield and so as to reduce the water depth in the basin. He observed that there was augmentation in the productivity of still when it was coupled with ETC. The productivity was increased from 1965 ml for passive solar still to 3910 ml for active solar still. Thus increase in yield for active solar still was 49.7% higher than that of passive solar still. This increase in yield was also higher than solar still coupled with FPC [7, 8], solar still coupled with parabolic collector [9] and solar still coupled with solar pond [10]. The author also observed that the use of black gravel increased the productivity. Use of black gravel gave 9.78% rise in yield for the solar still coupled with ETC. Payback period for the model was 235 days. From the economic analysis cost of production was found to be 12 INR/l.

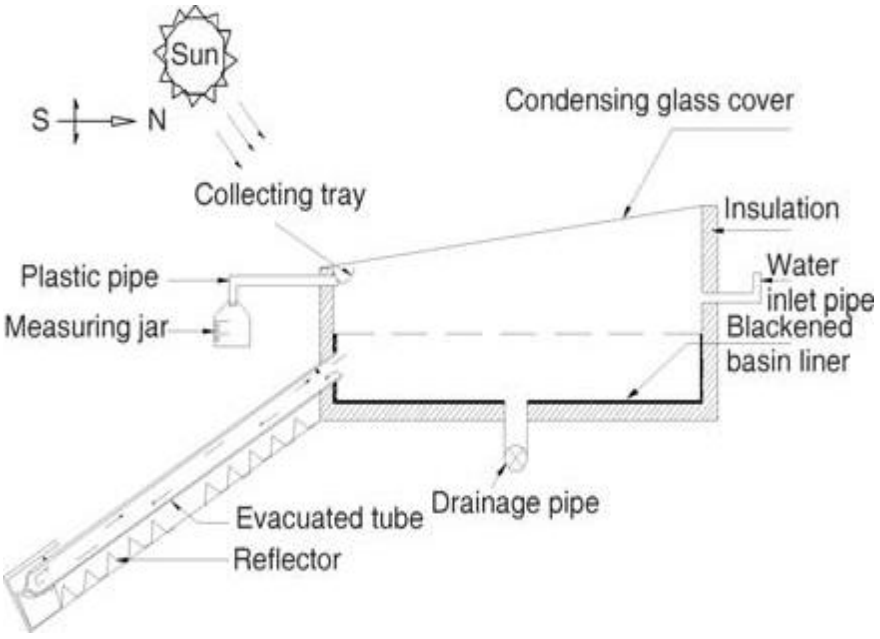


Fig. 1 Schematic of single slope solar still coupled with ETC [6]

Singh et al. [11] carried out thermal modelling of a single slope active solar still coupled with ETC. They estimated effect of water depth in basin on yield, energy and exergy efficiency. They optimized the system to find best combination of size of ETC and water depth in solar still. Using thermal simulation in MATLAB they calculated instantaneous temperature of water in basin, temperature of water in collector, inner glass temperature, outer glass temperature to estimate yield and efficiency. They predicted maximum natural circulation rate of 44 kg/h, maximum water temperature of 94°C, daily yield of
3.8 kg/m^2 and energy and exergy efficiencies of 33% and 2.5% respectively. They found that for 1 m^2 area and 0.03 m water depth, ETC having 10 tubes is most suitable.

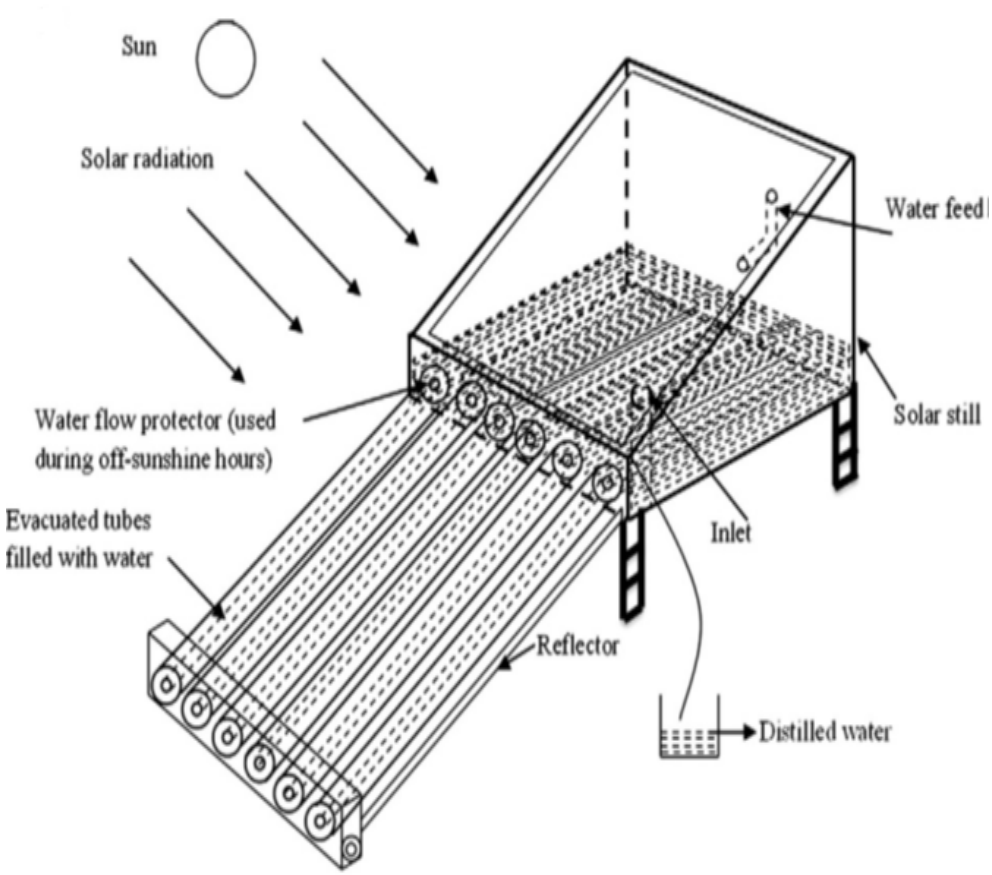
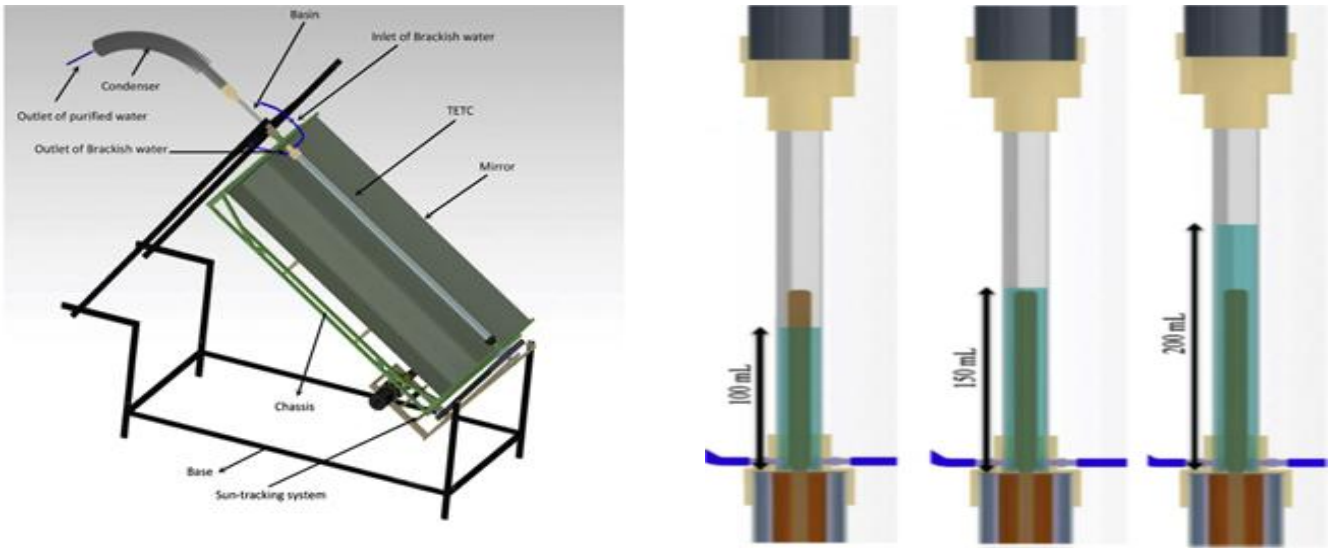


Fig. 2 Schematic of solar still coupled with ETC in natural mode [11]

2.1.2 Evacuated tube collector with heat pipe with parabolic trough collector

Mosleh et al. [12] developed Twin-glass Evacuated Tube Collector (TETC) with heat pipe coupled with parabolic trough collector as shown in Fig. 3 (a). A microcontroller based sun tracking system was installed to have maximum solar heat gain. Their research was focused on experimentally calculating the time constant, acceptance angle, effect of water level in basin on productivity and effect of using aluminum foil, oil and water in the space between TETC and heat pipe on productivity. The time constant and half acceptance angle were found to be 67.5s and 2.41° respectively. Different water levels viz. 100 ml, 150 ml and 200 ml were taken in basin (Fig. 3 (b)). Maximum yield of 0.933 kg/m^{2}h was achieved at 150 ml when oil was filled in the space between TETC and heat pipe. With the use of aluminum foil, water and oil in the space between TETC and heat pipe, efficiency was 21.7 %, 42.2 %, 65.2 % respectively.



(a) (b)

Fig. 3 (a) Twin-glass Evacuated Tube Collector with heat pipe coupled with parabolic trough collector (b) different levels of water in the basin [12]

2.2 Active solar still coupled with ETC without reflector

In this kind of active solar still, ETC is coupled with solar still without any reflector beneath it. So aperture area for such collector is less compared to that with the reflector.

2.2.1 Single basin active solar still coupled with ETC without reflector

Solar still coupled with ETC with natural circulation of saline water through ETC was developed by Sampathkumar et al. [13]. Their main focus was on productivity enhancement. Authors have also experimented passive solar still for comparison purpose. They concluded that higher basin temperature is achieved with active solar still which results in higher yield. Maximum yield of 7.03 kg (3.43 kg/m^2) and 3.225 kg was observed with active and passive solar still respectively. They reported 129% and 83% rise in yield respectively during day and night with active solar still compared to passive solar still. During peak hours, thermal efficiency of active solar still was found less than the passive solar still as heat loss is more compared to useful heat gain with higher temperature. Authors also suggested future scope for the research which includes development of active solar still coupled with (ETC) in forced circulation mode, optimizing the number of evacuated tubes, their angle of inclination to increase yield and reducing heat loss in order to increase the efficiency of active solar still.

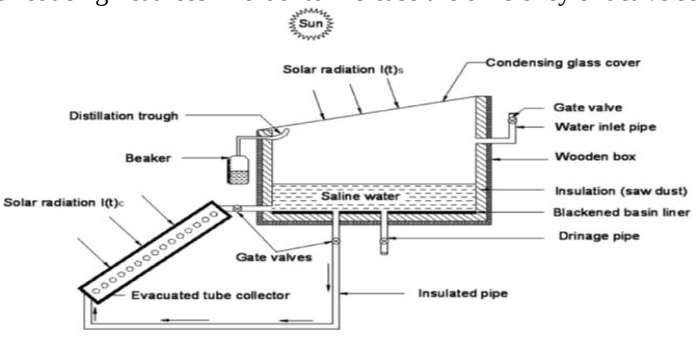


Fig. 4 Schematic of an active solar still with ETC with reflector [13]

Mamouri et al. [14] developed a solar still coupled with ETC having five evacuated tubes with thermosiphon heat pipe. The focus of the research was on effects of water depth, basin cover material and intensity of the solar radiation on the rate of production. Condenser part of heat pipe having 20 mm length was kept in basin as shown in Fig. 5. Three materials viz. glass, steel and aluminum were used as the basin cover material. Rate of production was found maximum 1.02 kg/m^{2}h in

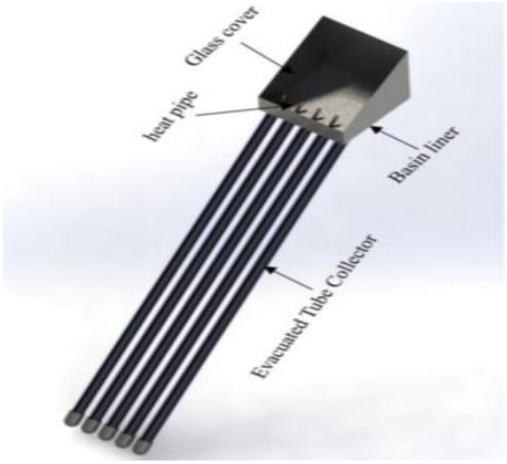


Fig. 5 Proposed model of solar still coupled with ETC with thermosiphon heat pipe [14]

case of glass cover. Still efficiencies were found 22.9%, 17.5%, 8.3% with glass, aluminum and steel covers respectively. Depth of water in basin was in the range of 1 to 5 cm and optimum depth concluded was 2 cm. They observed that with increase in water depth, thermal capacity of basin increases which result into decrease in distillate output. Rate of production was proportional to solar radiation. From the economic analysis cost of production was found to be 0.62 INR/l/m^2.

Tiwari et al. [15] developed thermal model for active solar still coupled with FPC, concentrating collector, ETC with and without heat pipe. They experimentally validated thermal model for active solar still coupled with FPC. The maximum values of total heat transfer coefficient for active solar still coupled with FPC, concentrating collector, ETC with and without heat pipe were 43, 86, 67 and 76 W/m^2K respectively. Daily total yield for active solar still coupled with FPC, concentrating collector, ETC with and without heat pipe were 3.19, 4.08, 4.00, 4.24 kg/m^2day respectively. Overall thermal efficiency of active solar still coupled with FPC, concentrating collector, ETC and ETC with heat pipe were 13.14, 17.57, 17.22 and 18.26 % respectively.

Sampathkumar and Senthilkumar [16] developed a novel system of active solar still. According to their survey, solar water heaters are used only during cold weather in India. Hence heat stored in water is literally wasted during summer season. So, they developed an experimental model as shown in Fig. 6, where an ETC

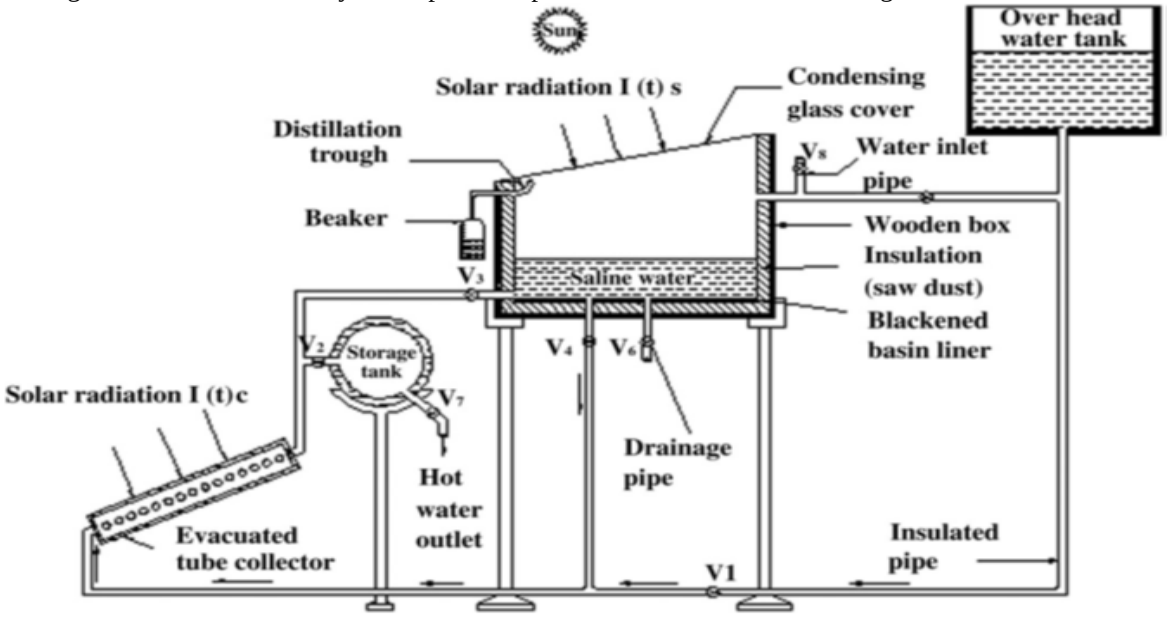


Fig. 6 Schematic view of ETC based solar water heater coupled with solar still [16]

based solar water heater was coupled with solar still to raise the water temperature in basin. They also developed and validated theoretical model with experiment. The focus of their experiment was on inner glass cover temperature, water temperature in basin and distillate yield. They considered 5 different cases for experiment which consist duration for connection between ETC based solar water heater and solar still in order to cope up with seasonal situational requirement throughout a year. Authors found that yield for solar still coupled with ETC based water heater was double compared to passive solar still. If both the systems were coupled after 60°C temperature of water storage tank than 77% more yield was achieved compared to passive solar still. Distilled water was tested and compared with BIS and WHO standards and was found safe for drinking purpose.

2.2.2 Double basin active solar still coupled with ETC without reflector

Panchal and Shah [17] investigated a double basin active solar still coupled with evacuated glass tube. Schematic of their system is shown in Fig. 7. They found that yield in case of double basin solar still is more than single basin conventional

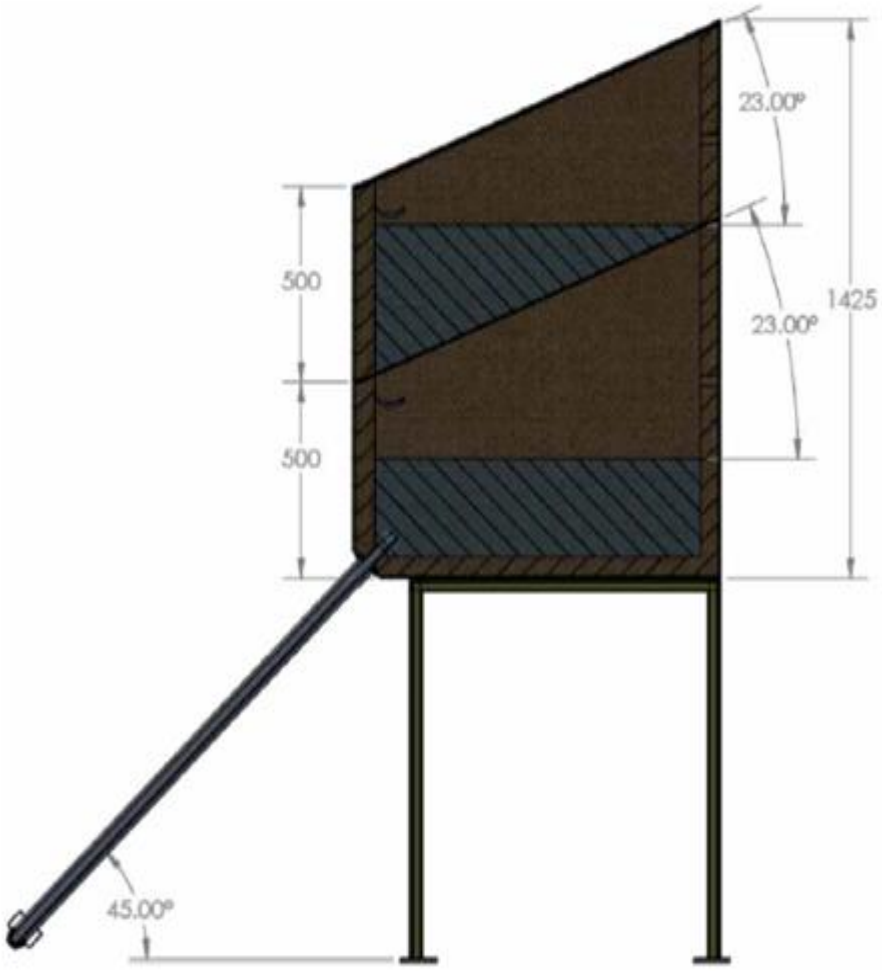


Fig. 7 Schematic of double basin active solar still coupled with evacuated glass tube [17]

solar still. Higher yield was due to use of latent heat of condensation of lower basin to raise temperature of water in upper basin. This also helps in decreasing the inner glass cover temperature of lower basin. Experiments were carried out at Mehsana, Gujarat for the whole year of 2013. It was found that during day time as the water depth increases yield decreases and vice-versa was the case during night time. Authors found maximum and minimum yield in the month of May and December respectively. Maximum yield of 11.064 kg was obtained for water depth of 0.03m in the month of May. An average daily yield for the year was 8 kg. From the economic analysis cost of water was calculated to be 0.37 INR/kg.

3 Active solar still coupled with ETC in forced circulation mode

Shiv Kumar et al. [18] developed a solar still coupled with ETC in forced circulation mode. Annual yield obtained was 567.3 kg/m^2 which was higher compared to natural circulation [11] and hybrid PV-T active solar still [19]. Authors found optimum performance at water depth of 0.03 m in basin with mass flow rate of 0.06 kg/s. Corresponding energy and exergy efficiencies were 33.8% and 2.6% respectively with daily yield of 3.9 kg (1.72 kg/m^2 of aperture area). They also presented economic analysis and cost of distillate water of 2.01 INR/kg and payback period of 3.7 years (considering selling price of distillate as 6.0 INR/kg) were calculated.

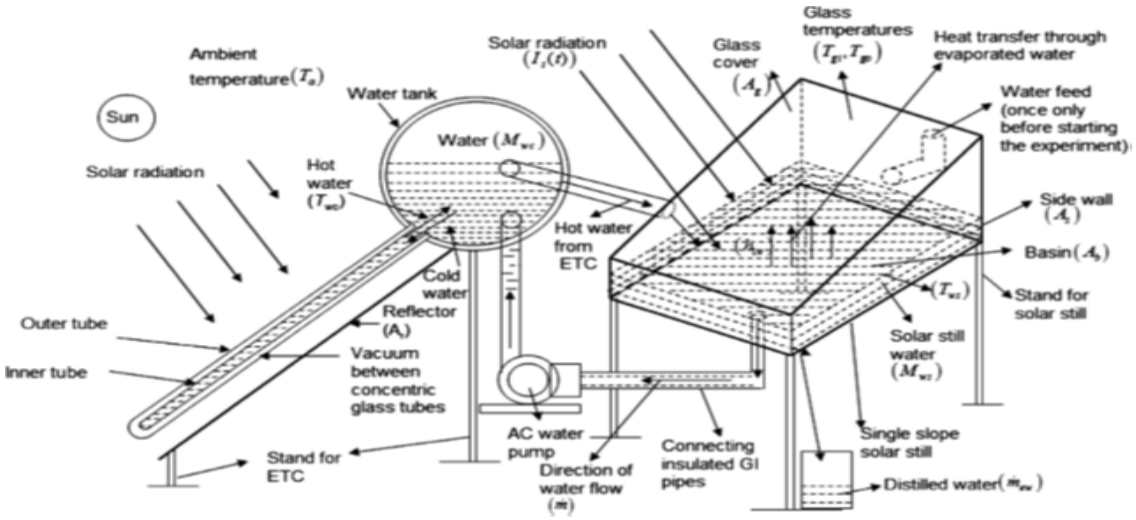


Fig. 8 Schematic of solar still coupled with ETC in forced circulation mode [18]

Dev and Tiwari [20] carried out an experimental investigation on Evacuated glass tube Integrated Solar Still (EISS). They developed a model in which ETC based water heater was coupled with solar still under forced circulation mode through an AC pump. Schematic of their model is shown in Fig. 9. Experiments were carried out from January to December of 2008. Temperatures of inner glass cover, outer glass cover, basin liner, water and ambient, velocity of wind, solar insolation and yield were measured hourly for representative day of January and February (winter), and May and June (summer). Value of yield was found higher for summer months because of low temperature difference between water and ambient and vice-versa for winter season. Maximum yield of 3.328 kg/m^2 was observed in the month of May. Annual yield for active and passive solar still was found to be 630 kg/m^{2}year and 327 kg/m^{2}year respectively. Maximum and average thermal efficiency of active solar still was found to be 29.9% and 21.3% respectively. Annual cost of production of distilled water was 6.15 INR/kg for the water depth of 0.05 m and average production rate of 2.5 kg/m^2.

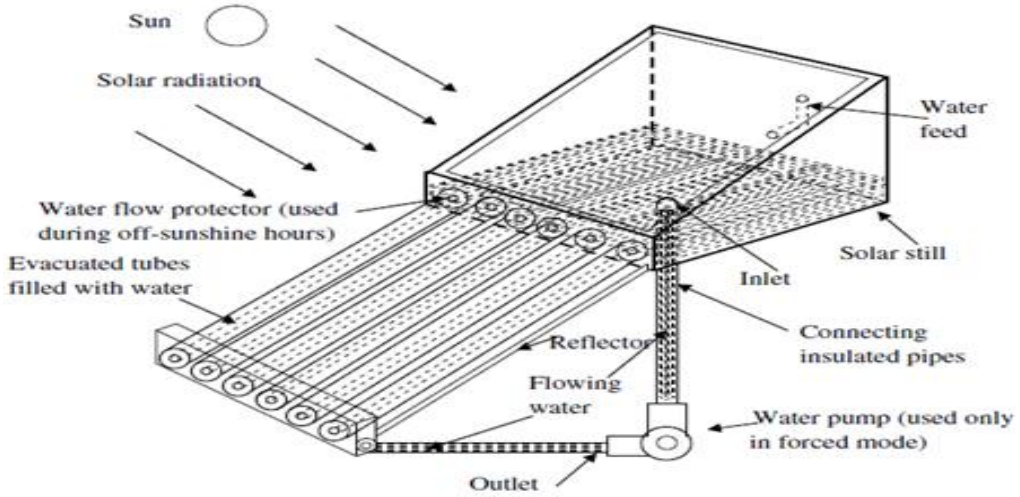


Fig. 9 Schematic of Evacuated glass tube Integrated Solar Still in forced circulation mode [20]

Conclusion

After reviewing work done by various researches on active solar still coupled with evacuated tube collector, following conclusions can be drawn.

- Comparison of daily yield, maximum hourly yield and efficiency for different systems is given in Table. 1.
- Active solar still gives higher yield compared to passive solar still. But on the other side active solar still has lower energy and exergy efficiencies compared to passive solar still because of higher ratio of heat loss to the useful heat gain.
- Evacuated Tube Collector is proved to be economical and efficient compared to Flat Plate Collector and Concentrating Parabolic Collector (CPC).
- Instead of using larger area of basin for higher yield, the area should be replaced by ETC to reduce the significant heat loss. Hence productivity can be increased with smaller area and less heat loss.
- Using double basin solar still latent heat of vaporization of lower basin can be utilized to increase the temperature of water in upper basin and hence productivity can be increased.
- Glass is found to be the best suitable material for the top cover of basin compared to steel and aluminum.
- For evacuated glass tube with heat pipe higher conductive material (like oil) should be used in the space between glass tube and heat pipe to increase the heat transfer.
- With the use of reflector with ETC, significant increase in efficiency can be achieved.
- With the use of black gravels and pebbles, yield can be increased as these materials enhance thermal storage capacity.
- Forced circulation of water gives higher yield compared to natural circulation due to higher heat removal from ETC.

Table 1. Comparison of yield and efficiency for different studies

Author	System description	Average daily yield (kg/day)	Maximum hourly yield (kg/m^2h)	Average Efficiency (%)
Sampathkumar [6]	Natural circulation of water through ETC and use of black gravels as thermal storage media	3.91	0.85	-
Singh and Kumar [11]	Natural circulation of water through ETC with reflector (theoretical prediction)	3.80	0.60	33
Sampathkumar et al. [12]	Natural circulation of water through ETC	5.70	1.12	-
Mosleh et al. [13]	ETC with heat pipe and parabolic trough collector in natural circulation	4.03	0.93	65.2
Momouri et al. [14]	ETC with thermosiphon heat pipe	6.35	1.02	22.90
Sampathkumar and Senthilkumar [16]	Natural circulation of water from ETC based solar water heater coupled with solar still	5.33	0.63	16.48
Panchal and Shah [17]	Double basin solar still with natural circulation of water through ETC	8.00	0.90	-
Shiv Kumar et al. [18]	Forced circulation of water through ETC	3.47	0.55	30.00
Dev and Tiwari [20]	ETC based solar water heater coupled with solar still in forced circulation mode	2.50	0.41	21.30

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Prediction of Students' Performance using Artificial Neural Network

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Abstract

Nowadays in the academic field it is very important to keep a check on performance of the students. By doing so the authorities can better the results of their institutes and also by knowing the capacity and performance of a student in prior, they can provide them help required for their upcoming exams and make them able to achieve the high goals. Here, in our model we had presented a study on Feed forward Back propagation network. The factors considered as relevant to student achievements are the marks of various standards, their travel time, study time etc., which are used as input variables to an ANN. A model prepared using Feed forward Back propagation network and trained using the collected data of students. The output obtained from the network is in the form of graphs representation which represents the accuracy. Implementation of such user-friendly software tool makes it easy for the user to classify and distinguish the students with low capabilities and achievements.

Keywords: student performance; Artificial Neural Networks; prediction; academic performance; Feedforward Backpropagation

Nomenclature

x	Input training vector
δ_k	error at output unit y_k
δ_j	error at hidden unit z_j
z_j	Hidden unit j
y_k	output unit k
α	Learning rate

1. Introduction

Students, their parents and the educational institute authorities have become extremely concerned about the results and performance of the students during their academic years. Here we have prepared a predictive analysis model which can predict the future performance of students based on their past records and let their guardians know about their progress in the academics. By collecting the students' data and preparing a dataset with proper weights we had prepared our model. The data of the students consist of their 10th, 12th and JEE marks, also their study time, travel time and education of their parents are taken into consideration. Taking those marks and processing them with the help of feed-forward back-propagation we had used graphical representation to justify our output by comparing the actual and predicted outputs which are accurate and precise.

1.1Artificial Neural Network

Computer science and other research disciplines extensively use neural networks as a computational approach which is based on a large collection of artificial neurons.

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An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by biological nervous systems. It is composed of a large number of highly interconnected processing elements called neurons. An ANN is configured for a specific application, such as pattern recognition or data classification. Each neural unit is connected with many other units.

Its links can be responsible for the specific effect on the activation state of connected neural units. Each individual unit has a summation function which combines the values of all its inputs together. These systems are self-learning and trained. They are not explicitly programmed and they excel in areas where there is a difficulty in expressing it in a traditional computer program.

1.2Feed-forward Neural Network

A Feed-forward neural network is an artificial neural network. Here, the connections between the neurons do not form a cycle. The first and simplest type of artificial neural network devised was the Feed-forward neural network. The information in this network moves in only one direction. It moves only forward from the input nodes, through the hidden nodes and to the output nodes. No cycles or loops are formed in the network.

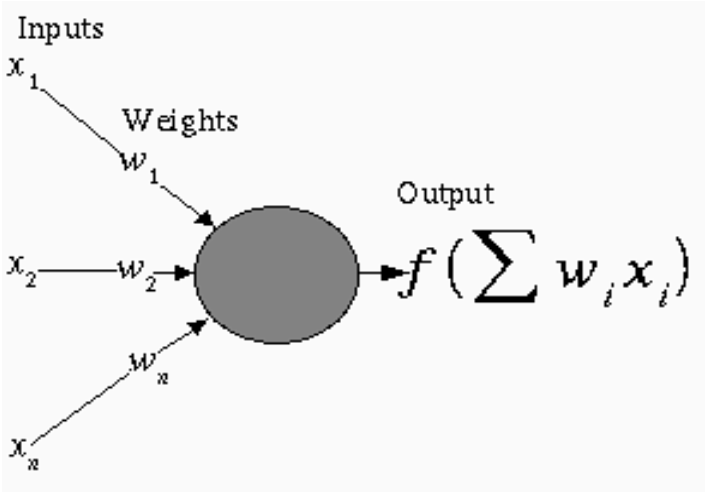

Fig. 1.2.1 Feed-forward Neural Network

1.3. Back propagation

As the name suggests, the errors propagate backward from the output nodes to input nodes through inner layers. It is used to calculate the gradient of the error of the network according to its weights. The input layer is connected to the hidden layer and the output layer is connected to the output layer through weights. More the number of hidden layers more is the complexity of the network. As a result, the time taken to compute the errors may be high.

The weight updation for output unit is given by $\Delta w_{ik} = \alpha\delta_k z_j$

The weight updation for hidden unit is given by $\Delta v_{jk} = \alpha\delta_j x_i$

2. ANN Evaluation

A huge expansion in the field of education has been seen in the recent times. Students, their parents and the educational institute authorities have become extremely concerned about the results and performance of the students during their academic years. More and more new technologies have been developed which help students in their academic years to achieve good results. Here we have prepared a predictive analysis model which can predict their future performance based on their past records and let the guardians of the students know about their progress in the academics. Knowing the progress well in advance the students can better their results. If it is not up to the mark then their institutes can help them in achieving the desired results by providing additional support such as additional learning activities, resources and learning tasks. By doing so even the institutes will be benefitted as their institute will be considered as the one providing good education to the students. The use of Artificial Neural Networks has been increased in the recent times as it is very much helpful for such predictive analysis. We had taken the help of ANN for preparing our predictive model. The datasets

taken to prepare the model is trained by the neural nets so as to give us the desired output. The output that we desire is compared with the output which we have got and it had an acceptable accuracy to successfully complete our model.

The dataset is created by collecting the students' data and assigning them proper weights. Assigning weights to the dataset was the most important part of preparing the predictive model. If the weights were not assigned properly, then the desired accuracy will not have been achieved. The data of the students consist of their 10th, 12th and JEE marks, also their study time, travel time and education of their parents had taken into consideration. The dataset formed was in an excel sheet from which the data was copied to the input window of NN tool and the target data was copied to the target window. The entered data then trained and tested by using the Feed-forward back-propagation method to generate the output which was accurate and precise. The graphs which were generated are of four types, testing, training, validation and overall.

The implementation of our model has been done using MATLAB tool. It is intended primarily for numerical calculations, which is why we chose it for our model. It provides a large number of toolboxes to work with. Neural Network Toolbox is one of the many toolboxes available in MATLAB and it is the best fit for our model The accuracy is the most important part of any predictive analysis model similarly is plays a very vital role in our model also it gives us not exact but near to accurate results. By analyzing the performance of their children parents can take necessary measures to improve their child's performance in the following semester or year if the predictive result is not so good. Although if the predictive result is in favor then also it can be useful to keep the track of the academics. The parameters used for the dataset are SSC & HSC marks, JEE marks, Study time, Travel time, Parents' Education, Extra-Curricular Activities, Employment and Addiction. These parameters are transformed into a format suitable for neural network analysis.

Table 2.1 Input Data

Sr. No	Input Parameters	Domain	Class
1	SSC & HSC marks	(100-90)	10
		(89-80)	9
		(79-70)	8
		(69-60)	7
		(59-50)	6
		(49-40)	5
		(39-30)	4
		(29-20)	3
2	JEE marks	(360-240)	5
		(239-180)	4
		(179-120)	3
		(119-60)	2
		(< 60)	1
3	Study Time	(8-10)	5
		(6-8)	4
		(4-6)	3
		(2-4)	2
		(0-2)	1
4	Travel Time	(0-1)	5
		(1-2)	4
		(2-3)	3

		(3-4)	2
		(4-5)	1
5	Parents' Education (Father-f, Mother-m)	(f-m) Grad	5
		(f/m) Grad	4
		(f-m) HSC	3
		(f/m) SSC	2
		Uneducated	1
6	Extra-Curricular Activities	Rare	3
		Sometimes	2
		Often	1
7	Employment	Yes	1
		No	2
8	Addiction	Yes	1
		No	2

Table 2.1 shows the parameters used in the dataset and their corresponding values taken for training. For every parameter the domain has been assigned the values in a certain range and each of its corresponding class values has been mentioned as the system evaluates on the basis of numerical value.

Table 2.2 Output Data

Sr No.	Output Variable	Domain	Grade	Class
1	Good	1st Class	(8.0-10.0)	1
2	Average	2nd Class	(6.0-7.9)	2
3	Poor	3rd Class	(3.0-5.9)	3

In Table 2.2, the output variable represents the performance of a student. The classification of output variable domain chosen above is Good, Average, Poor so that the students can be classified as per their capabilities and necessary actions can be taken for every student as and when required [7].

After training the network using sample dataset which consists of real time data of 150 students, then the predicted output was compared with the target output which is our actual output and is presented in the form of graphs. We use three parts of dataset regression. In Fig 2.1, the graphs shown are training, testing, validation and all phase regression analysis of the network. Where dash line represents the target and solid line represents the best fit linear regression line between outputs and targets.

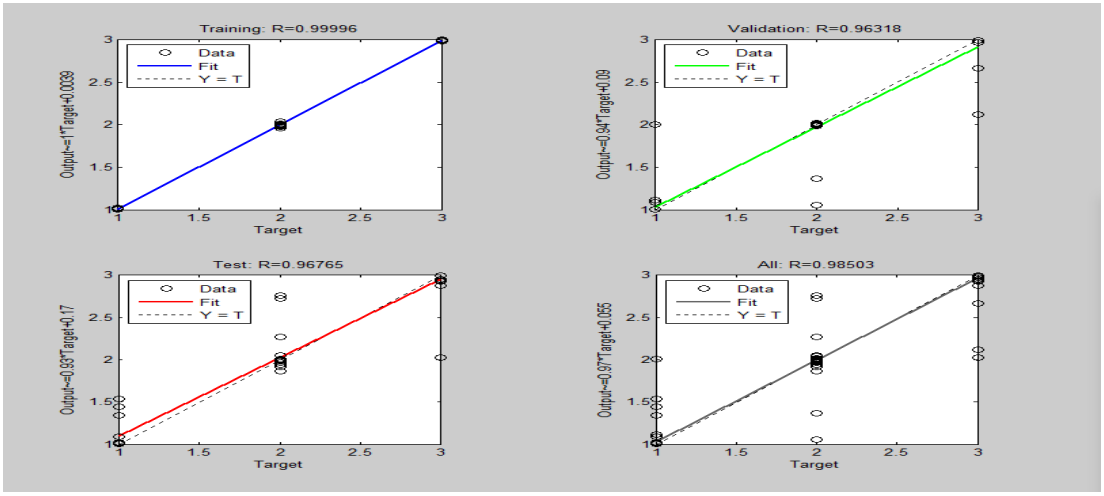

Fig. 2.1 Regression Graph

The Mean Squared Error (MSE) is a measure of how close a fitted line is to data points. The smaller the MSE, the closer the fit is to the data. After running the neural network we have the predicted result. The result is best validated at 5 epochs out of 11 epochs [16]. Fig 2.2 shows the performance of the neural network. The dot in the figure represents best results. We observe validation results touch our dot line at 5 epochs and the performance is 0.030941 which represents performance accuracy is around 98%.

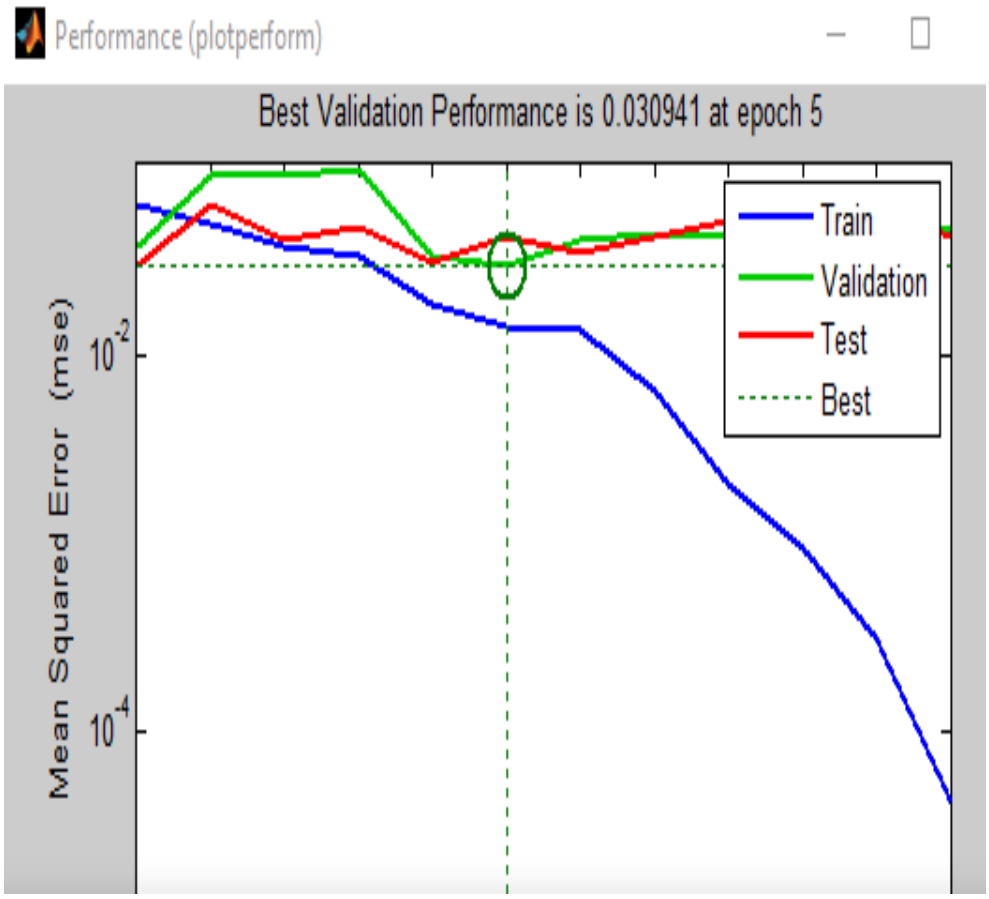

Fig. 2.2 Performance Platform

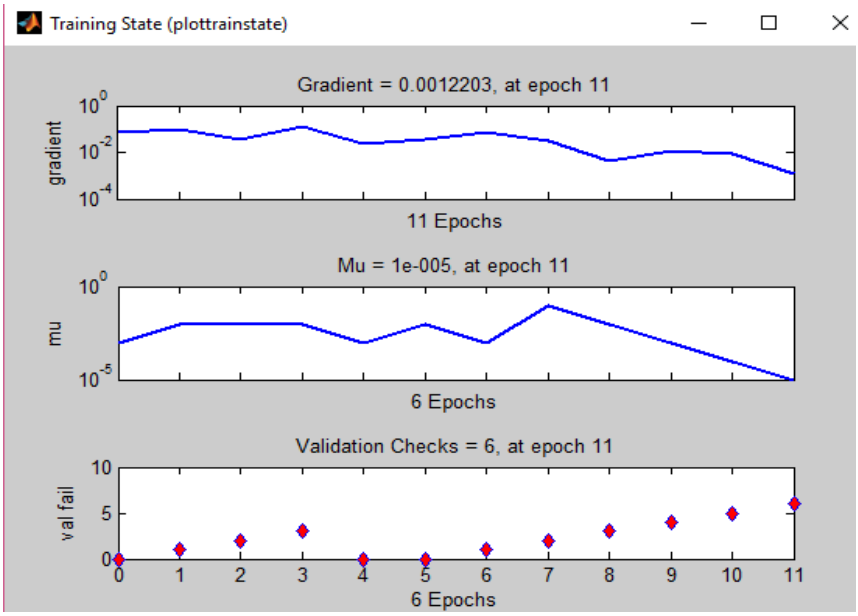

Fig 2.3 Training State

3. Conclusion

This paper presents Feed-Forward Back-Propagation based prediction models to predict students' performance based on multiple factors. From the findings, the Feed-Forward Back-Propagation model achieved an accuracy of 98%. It shows the potential efficacy of Artificial Neural Network as a prediction tool and such a criterion for students which can help them to get better result. These types of models can evolve our education system as teachers and parents can have an idea in advance about their children's performance in the next year and they can try to improve their result by giving these students special sessions or personal teaching. These types of models can also be prepared using some other techniques of Neural Network but till now we had tried only once. A comparative analysis of different techniques can also done in future.

4. Acknowledgements

We have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. We would like to extend our sincere thanks to all of them.
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Assessment of Water Quality Parameters of Vishwamitri River

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Abstract

This paper presents an extensive investigation of physico-chemical parameters of surface water samples collected from Vishwamitri River. Total 42 Samples were collected from 7 sampling stations. Samples were collected during pre-monsoon, monsoon and post-monsoon seasons from April 2015 to March 2016 with the objective to assess the variation occurring in water quality parameters with changing flow conditions during different seasons. It is found from the obtained results that important indicators of pollution, such as biological oxygen demand (BOD) and chemical oxygen demand (COD) were found to be lowest whereas dissolved oxygen (DO) level increased during monsoon period. However, Total Suspended Solids (TSS) and Turbidity is found more during monsoon and post-monsoon season. This study replicates important role of maintaining the consistent perennial natural flow in reducing pollution levels of aquatic systems.

Keywords: Physico-chemical parameters, Statistical analysis, Vishwamitri River, Water Quality,

1. Introduction

A river's water quality is highly governed by local and temporal variations [1-3]. The physical, chemical and biological processes in a river reach can also be affected by the volume of water flow [4]. Heavy industrialization and increasing urbanization reflect alarming pollution level in river [5]. The poor sanitation and living conditions of people in settlements around rivers, deposition of domestic and sewage waste, release of industrial waste without appropriate treatment, non availability of STPs and CETPs for treatment of water from urban areas are the major reasons for pollution of Indian rivers [6]. River water, utilized for agricultural, industrial, and domestic uses, has to concurrently provide eco-environmental water in terms of Environmental Flows (EF) for riverine system to ensure the continued functioning of ecological processes that provide much needed goods and services for human use and maintenance of biodiversity. Therefore, it is necessary to consider these both functions of river water in water resources management. However, the higher the flow variability of a river, the smaller the Environmental Flow Requirements (EFR), whereas river stretches with less flow variability deems higher EFR [7]. Analyses of surface waters for physico-chemical and microbiological parameters are essential integral components in assessing the impact of various anthropogenic activities on water bodies [8] and give a fair estimate of EFR on spatial and temporal scale.

The Vishwamitri river originates from the Pavagadh hill at about 22°30' N latitude and 73°45' E longitude. The Vishwamitri is a seasonal river which flows east to west between the Mahi and Narmada rivers in Gujarat. Vishwamitri is a major tributary of Dhadhar river, which merges with Arabian Ocean. Vishwamitri watershed comprises of 9-mini-watersheds which cover a total area of about 1185 km^2 [9]. Surya and Jambuva rivers are two major tributaries of Vishwamitri. The historical Vishwamitri River is converted into a sewer draining most of the pollutants from its own catchment area. Various sources of pollution like sewage effluent disposal sites, industrial effluent disposal sites, landfill sites, slums, etc. were observed while monitoring the various stretches of Vishwamitri. The upstream stretch of Vishwamitri before it enters in Vadodara city, is surrounded with rural as well as industrial development. This upstream stretch of Vishwamitri is affected with the release of partially treated or untreated sewage from villages and industrial effluents. Fishing and cattle washing activities are predominant in this stretch. The River flows west through the Vadodara city in the middle of its 21.80 km stretch with less carrying capacity and less velocity. This stretch of river is affected by stormwater drains flowing mainly sewage, industrial waste water and solid waste.

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River Vishwamitri, although passing through densely populated areas of Vadodara city, supports a healthy breeding population of Crocodyluspalustris commonly known as "Mugger". River is also surrounded by solid waste dump sites, sewage treatment plants and recreational sites [10]. The pollution resulting in Vishwamitri is largely due to less flow and discharge of the untreated sewage, which enters through various points across the stretch of the river in the city. Jambuva River, collecting sewage from Vadodara city, merges at the downstream stretch of Vishwamitri. The villagers living on the bank of the river as a downstream users are unable to use the river water for drinking purpose. They need to go far away to find drinking water source. The downstream water is used for irrigation purpose by the adjoining farms, though it is found medium to very bad for irrigation purpose [11]. The flow in Vishwamitri very low except in rainy season. River mainly flows in the month of July, August, and September [12]. The river ceases flowing in the dry season due to diversions of river water at its upstream during rainy season to Ajwa reservoir. Also, the river being non-perennial, the water flowing in the river for the most part of the year is nothing but sewage let out which has made the river odorous at some locations. It is the need of the hour to take maximum benefits of river water by ensuring required quantity and quality of water flow to sustain life. This can be initiated through exploring preliminary environmental flow requirements of Vishwamitri through its qualitative assessment. In this paper, the efforts are made to assess the water quality of Vishwamitri through analyses of various physico-chemical and indicative parameters of water samples in terms of descriptive statistics. Through such assessment various hot spots with heavy pollution load along the river can be extracted. This study is also an integral component for assessing environmental flow requirements in order to restore Vishwamitri.

Study area

Based upon the location of the point and non-point sources of waste discharges, seven sampling (Two stations- in upstream stretch, Three stations- in the middle stretch within Vadodara City and Two stations- in the downstream stretch) along the Vishwamitri were being selected. Geographical locations of all sampling stations were been ascertained using hand held Garmin GPSMAP 78s Global Positioning System device. Details of all seven sampling stations with their surrounding conditions are given in Table 1. Sampling stations along the Vishwamitri are shown in Figure 1.

TABLE 1. DETAILS OF SAMPLING STATIONS ALONG VISHWAMITRI RIVER

sStation No.	Distance from origin (km)	Geographical location	Essential
S-1	14.30	43Q0335564, UTM 2485196	River flow is usually diverted to Ajwa reservoir at upstream of this site. At this location, the river receives flow various reservoirs and tributaries passing from rocky strata of Pavagadh hill.
S-2	59.70	43Q0316049, UTM 2473459	The site represents Vishwamitri river contributed through flow from two major tributaries i.e. Surya river and Galiath river.
S-3	68.50	43Q0313430, UTM 2468083	The site represents the state of river contributed by various stormwater drains like Bhukhi Kaans, Bahucharaji Kaans, etc. flowing partially treated/ untreated sewage through Vadodara city.
S-4	72.90	43Q0311536, UTM 2464414	A site represents the state of river contributed by stormwater drains from Parashuram slum areas, Muj Mahuda. This site is just at downstream side of the solid waste dump site and Sewage Treatment Plant (STP) at Muj Mahuda village.
S-5	88.10	43Q0310288, UTM 2456884	The site represents the river at immediately downstream of the Vadodara city. This site receives drains from industrial areas of Maneja and Makarpura.
S-6	93.30	43Q0308731, UTM 2453914	This site represents Vishwamitri after merging of Jambuva river, a major tributary of Vishwamitri.
S-7	100.00	43Q0305700, UTM 2450951	This site represents a downstream stretch of Vishwamitri River.

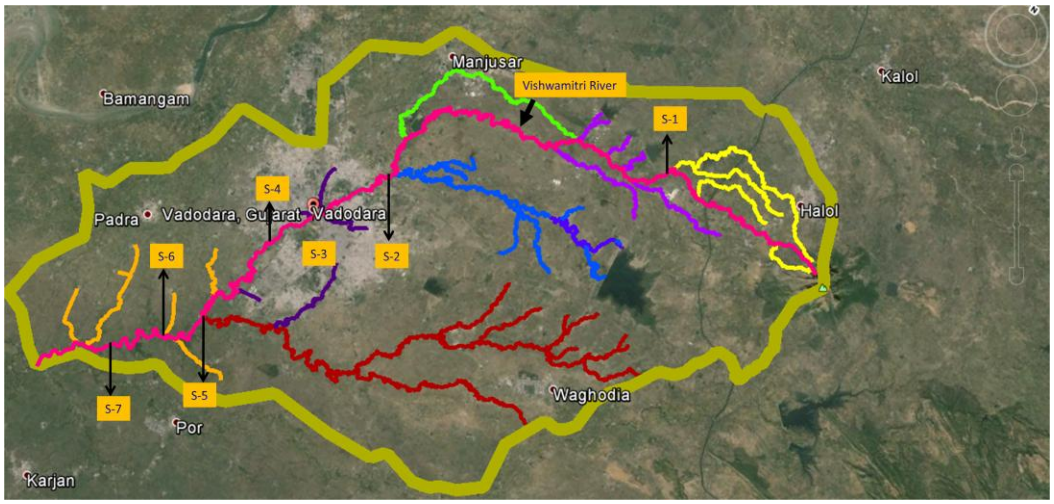

Fig. 1 Watershed of Vishwamitri along with tentative locations of sampling stations along the river

2. Methodology

The present work deals with the analysis of general physico-chemical parameters like Dissolved Oxygen (DO), Temperature (Temp), Turbidity (TB), pH (Hydrogen Ion Potential), Total Hardness (TH), Chlorides (Cl), Total Dissolved Solids (TDS), Calcium (Ca), Magnesium (Mg), Sulphate (SO_4), Nitrates (NO_3), Fluorides (F), Total Alkalinity (TA), Stream Velocity (SV). The indicative parameters like Total Suspended Solids (TSS), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were also analysed keeping in view the flow of water and discharge of waste water in the river. Samples were collected from seven sampling stations along the Vishwamitri (S-1, S-2, S-3, S-4, S-5, S-6 and S-7) during pre-monsoon, monsoon and post-monsoon seasons from April 2015 to March 2016.

The grab samples were collected in 2L clean polyethylene plastic containers labeled for respective station number, placed and transported in ice box to laboratories. The physico-chemical parameters like DO and Temperature were analyzed on site. All parameters were analyzed as per Bureau of Indian Standards (BIS) [13] and standard methods prescribed by APHA (1998) guidelines [14]. Stream Velocity (SV) is measured at all sampling locations with the help of cup type water current meter.

3. Statistical Analysis and Results

The values of various general physico-chemical parameters, observed at various sampling stations during pre-monsoon, monsoon and post-monsoon, are analyzed with univariate descriptive analysis. The result obtained in terms of mean and Standard Deviation (SD) and Standard Error (SE) is shown in Table 2.

Table 2. Statistical Assessment of Physico-Chemical and Microbiological characteristics of Vishwamitri River

Parameters	Pre-Monsoon				Monsoon				Post-Monsoon			
	Min.	Maxi.	Mean ± SD	SE	Min.	Maxi.	Mean ± SD	SE	Min.	Maxi.	Mean ± SD	SE
DO (mg/L)	0.30	11.90	3.28 ± 2.83	1.07	0.70	9.10	3.57 ± 2.91	1.10	0.60	8.10	1.83 ± 1.96	0.74
Temp (^{O}C)	29.00	37.30	32.54 ± 1.82	0.69	25.30	34.70	29.65 ± 0.94	0.35	18.50	28.70	25.24 ± 1.85	0.70
TB (NTU)	9.00	25.00	14.21 ± 3.99	1.51	13.00	50.00	25.43 ± 5.78	2.19	20.00	50.00	28.71 ± 6.54	2.47
pH	6.81	7.69	7.19 ± 0.24	0.09	6.62	7.90	7.18 ± 0.37	0.14	6.70	7.97	7.18 ±0.40	0.15
TH (mg/L)	132.00	326.00	253.14 ± 69.03	26.09	128.00	278.00	206.00 ± 50.80	19.20	128.00	358.00	222.57 ± 70.02	26.46
Cl (mg/L)	48.00	260.00	154.57 ± 67.46	25.50	40.00	168.00	110.29 ± 49.77	18.81	24.00	180.00	114.00 ± 59.88	22.63
DS	230.00	970.00	645.36	95.32	265.00	710.00	489.50	65.45	180.00	690.00	458.57	71.86

(mg/L)			± 252.18				± 173.16				± 190.13	
Ca (mg/L)	20.80	53.60	39.49 ± 8.12	3.07	27.20	46.40	36.69 ± 5.90	2.23	24.80	45.60	36.46 ± 6.40	2.42
Mg (mg/L)	12.00	50.88	37.06 ± 12.06	4.56	12.48	41.76	27.43 ± 9.18	3.47	9.12	58.56	31.54 ± 13.50	5.10
SO_4 (mg/L)	14.30	105.60	44.65 ± 24.05	9.09	8.58	99.00	49.26 ± 30.15	11.39	8.58	34.32	21.04 ± 7.42	2.80
NO_3 (mg/L)	4.84	30.51	11.59 ± 7.02	2.65	2.42	41.17	16.28 ± 5.30	2.00	9.69	36.33	19.89 ± 5.50	2.08
F (mg/L)	0.44	2.80	1.53 ± 0.12	0.046	1.42	2.20	1.82 ± 0.20	0.074	1.02	2.80	1.75 ± 0.50	0.19
TA (mg/L)	155.60	450.40	303.18 ± 81.62	30.84	64.00	350.80	181.60 ± 55.54	20.99	62.80	386.80	220.41 ± 89.41	33.79
Velocity (m/s)	0.00	0.66	0.30 ± 0.22	0.08	0.08	2.37	0.78 ± 0.53	0.20	0.10	1.15	0.60 ± 0.31	0.12
TSS (mg/L)	24.00	68.00	39.14 ±19.34	7.31	26.00	121.00	72.29 ± 37.41	14.14	30.00	154.00	93.57 ± 47.74	18.04
BOD (mg/L)	2.00	68.00	28.63 ± 25.38	9.59	2.80	20.00	13.83 ± 6.45	2.44	2.00	40.00	14.63 ±13.49	5.10
COD (mg/L)	4.00	199.00	88.00 ± 75.50	28.53	12.00	56.00	41.29 ± 18.22	6.89	8.00	127.00	57.29 ± 45.51	17.20

4. Discussion

The range of various parameters represented in Table 2 in terms of Mean ± SD can be considered with a confidence interval of 66%. Standard error for few parameters can be reduced with larger sample size. Essential regarding each physico-chemical parameter is discussed below.

Dissolved Oxygen

For the survival of aquatic organism and decomposition of waste by microorganism, adequate DO is necessary in riverine ecosystems [15]. The minimum concentration of dissolved oxygen should be 5.0 mg/L at 20°C or 57% dissolved oxygen saturation for the healthy condition of aquatic life, whereas the DO below 2 mg/L may lead to the death of most fishes in fresh water [16-17]. DO may be a potential indicator of river quality in assessing urban impacts on the river ecosystem [18-19]. DO value ranges between 0.3 mg/L to 11.90 mg/L. The minimum DO is observed at downstream station S-7 and maximum DO is observed at S-2 during pre-monsoon season. Various anthropogenic activities, release of partially treated sewage and domestic waste, increased temperature can be the reason for decreased DO value at S-7. S-2 is just downstream of tributaries Surya and Galiath. Flow in these tributaries is regulated. Release of flow through these tributaries would have increased DO even in pre-monsoon season.

Temperature

River water temperature is governed mainly by the quantum discharge of sewage, agricultural runoff and leachate from the heap of municipal solid waste along the banks of river and thermal pollution. Temperature governs to a large extent the biological species present and their rates of activity. Temperature governs microbial load in river ecosystem [20]. The variation in temperature in different seasons in the present study was mainly due to the climatic changes of the environment. Temperature value ranges between 18.5 ^{0}C to 37.7 ^{0}C. Temperature is observed minimum at S-2 during post-monsoon season, whereas, found maximum at S-7 during post-monsoon.

Turbidity

Turbidity measures water quality and due to suspended solid materials such as clay, silt, colloidal organic matter, planktons, and other organisms [21]. Turbidity value ranges between 9 NTU to 50 NTU. S-2 is observed with a minimum value of turbidity during pre-monsoon, whereas, S-4 and S-6 are found with maximum turbidity during post-monsoon and monsoon respectively.

Hydrogen Ion Potential

Hydrogen Ion Potential (pH) generally indicates the nature of water quality as acidic or alkaline. pH value ranges between 6.62 to 7.97. It is observed minimum at S-3 during the monsoon and maximum at S-1 in post-monsoon. Disposal of sewage and domestic wastes and pollutants draining from industrial areas through non-point sources (NPS) can be the possible reasons for the decrease in pH in monsoon season [22-23].

Total Hardness

Hardness is mainly due to cations like calcium, magnesium, strontium, iron and manganese. Bicarbonate and carbonate are anions responsible for hardness. Total hardness remains higher during summer than rainy season and winter season [24]. During pre-monsoon season, few of the sampling stations were representing higher values of total hardness than the desirable limit of 300 mg/L which may be due to low level of water and low velocity of water current [25]. The value of total hardness ranges from 128 mg/L to 358 mg/L. Total hardness is found minimum at S-1 and S-2 during post-monsoon and monsoon seasons respectively, whereas it is found maximum at S-4 during post-monsoon season. However, the mean value of total hardness remains high during pre-monsoon i.e. 253.14 mg/L.

Chlorides

It is observed that at most of the stations, the average values of chloride contents were lower in monsoon and post-monsoon seasons than pre-monsoon. Higher concentration of chloride content indicates heavy pollution [26]. Chloride value ranges between 24 mg/L to 260 mg/L. It was found minimum at S-1 during post-monsoon and observed maximum at S-7 during pre-monsoon.

Total Dissolved Solids (TDS)

Total dissolved solids give a direct measure of all the dissolved particles, both organic and inorganic in water. Effluent dumped from industrial estates are considered the main factor for the increase of dissolved solids in major rivers of Gujarat [27]. At most of the stations, the dissolved solids values had dropped down during monsoon and post-monsoon seasons compared to that in pre-monsoon. Value of dissolved solids ranges between 180 mg/L to 970 mg/L. It is observed minimum at S-2 during post-monsoon and found maximum at S-6 during pre-monsoon.

Calcium

The quantity of Ca in natural water generally varies from 10 to 100 mg/L depending on the type of rocks [28]. Calcium value ranges between 20.80 mg/L to 53.60 mg/L. Value of Calcium is found minimum at S-2 and maximum at S-3 during pre-monsoon. However, at all sampling locations during all seasons the Ca values were observed within desirable limit i.e. 75 mg/L. Mean value of Ca is observed more during pre-monsoon season.

Magnesium

Value of magnesium ranges from 9.12 mg/L to 58.56 mg/L. It is observed minimum at S-1 and maximum at S-4 during post-monsoon. Mean value of Mg is observed more during pre-monsoon season. However, Stations no. 4 to 7 have represented higher value of Mg than desirable limit, i.e. 30 mg/L in all the seasons.

Sulphate

Value of sulphate ranges from 8.58 mg/L to 105.60 mg/L. Value of sulphate is found minimum at S-1 during monsoon and post-monsoon season, whereas, it is observed maximum at S-7 during pre-monsoon. During the post-monsoon season the values of sulphate are lowered down significantly. However, at all the sampling stations the values of sulphate are found within the desirable limit (i.e. 300 mg/L) in all seasons.

Nitrates

The nitrate value ranges from 2.42 mg/L to 41.17 mg/L. It was observed minimum at S-2 and maximum at S-4 during monsoon. The mean value of N is observed more during monsoon, which can be due to the use of organic and inorganic fertilizer in the agricultural fields [29].

Fluoride

Fluoride concentration of approximately 1.0 mg/L in drinking water effectively reduces dental caries without harmful effects on health, but high concentration causes dental and skeletal fluorosis [30-31]. At most of the locations, the fluoride values found more than 1.0 mg/L. The value of Flouride ranges between 0.44 mg/L to 2.80 mg/L. It is observed minimum at S-5 during pre-monsoon and maximum at S-2 and S-3 during pre-monsoon and post-monsoon respectively. However, the mean concentration of F is observed more during monsoon and post-monsoon.

Total Alkalinity

At most of the sampling stations the average values of total alkalinity are found lowest during monsoon

season compared to pre-monsoon and post-monsoon seasons. Singh S. et al. (2015) also reported similar results in Gomati River [32]. The value of total alkalinity varies from 62.80 mg/L to 450.40 mg/L. It was observed minimum as S-2 during post-monsoon and maximum at S-3 during pre-monsoon.

Stream Velocity

Smaller rivers with low flow have less capacity to dilute and degrade potentially harmful pollutants [33]. Stream velocity is measured at various sampling stations. At most of the stations stream velocity is found more in monsoon season than pre-monsoon and post-monsoon seasons. The value of velocity ranges from 0.02 m/s to 2.37 m/s. It is observed minimum at S-2 during pre-monsoon and maximum at S-5 during monsoon. However, Vishwamitri is observed dry at S-1 during pre-monsoon.

Descriptive physical and biological parameters

Total Suspended Solids

Average values of total suspended solids increased in monsoon and post-monsoon seasons at most of the sampling stations, i.e. from station 3 to 7, which may be due to more flow during monsoon and post-monsoon seasons. Bamakanta et al. (2013) reported similar results for Nagavali River [34]. Value of total suspended solids ranges from 24 mg/L to 154 mg/L. It is observed minimum at S-5 during pre-monsoon and maximum at S-4 during post-monsoon.

Biological Oxygen Demand and Chemical Oxygen Demand

Unpolluted waters are having BOD values of 2 mg/L or less, whereas those receiving wastewaters may have values up to 10 mg/L or more and similarly COD values are observed 20 mg/L or less in unpolluted surface waters and greater than 200 mg/L in waters receiving effluents [17]. BOD value ranges between 2 mg/L to 68 mg/L. It is observed minimum at S-2 during pre-monsoon and post-monsoon and found maximum at S-3 during pre-monsoon. COD value ranges between 4 mg/L to 199 mg/L. It is observed minimum at S-2 and found maximum at S-3 during pre-monsoon. The mean value of both BOD and COD is reduced during monsoon and post-monsoon. However, BOD and COD values are found more from stations S-4 to S-7 in all seasons which may be attributed to the discharge of domestic wastewater from the upstream stretch of these stations.

5. Conclusion

The present study aims at studying spatial and temporal variation throughout the one year. The data collected from different sampling stations along the Vishwamitri discuss the pollution level of the river.

Viswamitri at its upstream stretch before entering into Vadodara city is affected mainly by release of industrial effluent, release of untreated sewage from villages, cattle washing, cloth washing, vehicle washing, release of uncertain flows from Surya and Galiath, the tributaries of Vishwamitri. In spite of this, Vishwamitri is rich with higher concentration of dissolved oxygen at its upstream stretch. Vishwamitri at its middle stretch after entering into Vadodara city is found affected by various anthropogenic activities like the release of untreated or partially treated sewage from various point sources, encroachment of river cross-section due to the development of urban slums, societies and commercial units on the banks, dumping of solid wastes on banks, recreational activities, release of industrial effluent with partial or without treatment. Vishwamitri is biologically dead in this middle stretch. Vishwamitri at its downstream stretch is highly inflated by discharge of industrial wastes with occasionally oil spilling, excessive use of fertilizers for irrigation and farming, use of water for cattle washing, cloth washing and extraction of water for irrigation. Temperature, concentration of chloride, magnesium and sulphate are also observed more in downstream stretch. The downstream stretch of the river is also found with more hardness and alkalinity. Flushing of pollutants towards downstream can be the reason for the same.

From the analysis of descriptive statistics, it can be concluded that Vishwamitri is having spatial and temporal diversity in terms of various water quality parameters. Through such analysis, various hot spots with heavy pollution load along the river can be extracted. Flow in river during various seasons governs the overall quality

of the river. Assessment of environmental flow requirements in order to restore Vishwamitri in its distinct stretches is crucial and for the same, continuous water quality monitoring programme as an integral component for Vishwamitri is need of the hour. The sustainable water quality management framework and strategic planning system with predefined mission, vision, goals, and objectives can be derived for Vishwamitri river basin [35].

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Abbreviations

APHA	American Public Health Association guidelines
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
Ca	Calcium
Cl	Chlorides
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
EF	Environmental Flows
EFR	Environmental Flow Requirements
F	Fluorides
Km	Kilometers
Mg	Magnesium
NO3	Nitrates
NPS	Non-point Sources
pH	Hydrogen Ion Potential
SE	Standard Error
STP	Sewage Treatment Plant
SD	Standard Deviation
SO4	Sulphate
SV	Stream Velocity
TA	Total Alkalinity
TB	Turbidity
Temp	Temperature
TH	Total Hardness
TSS	Total Suspended Solids

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